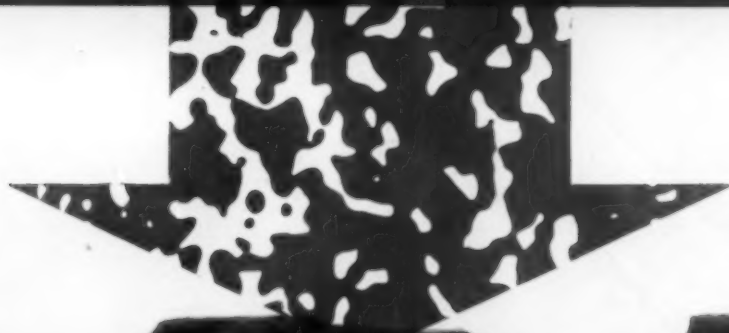


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.... page 37

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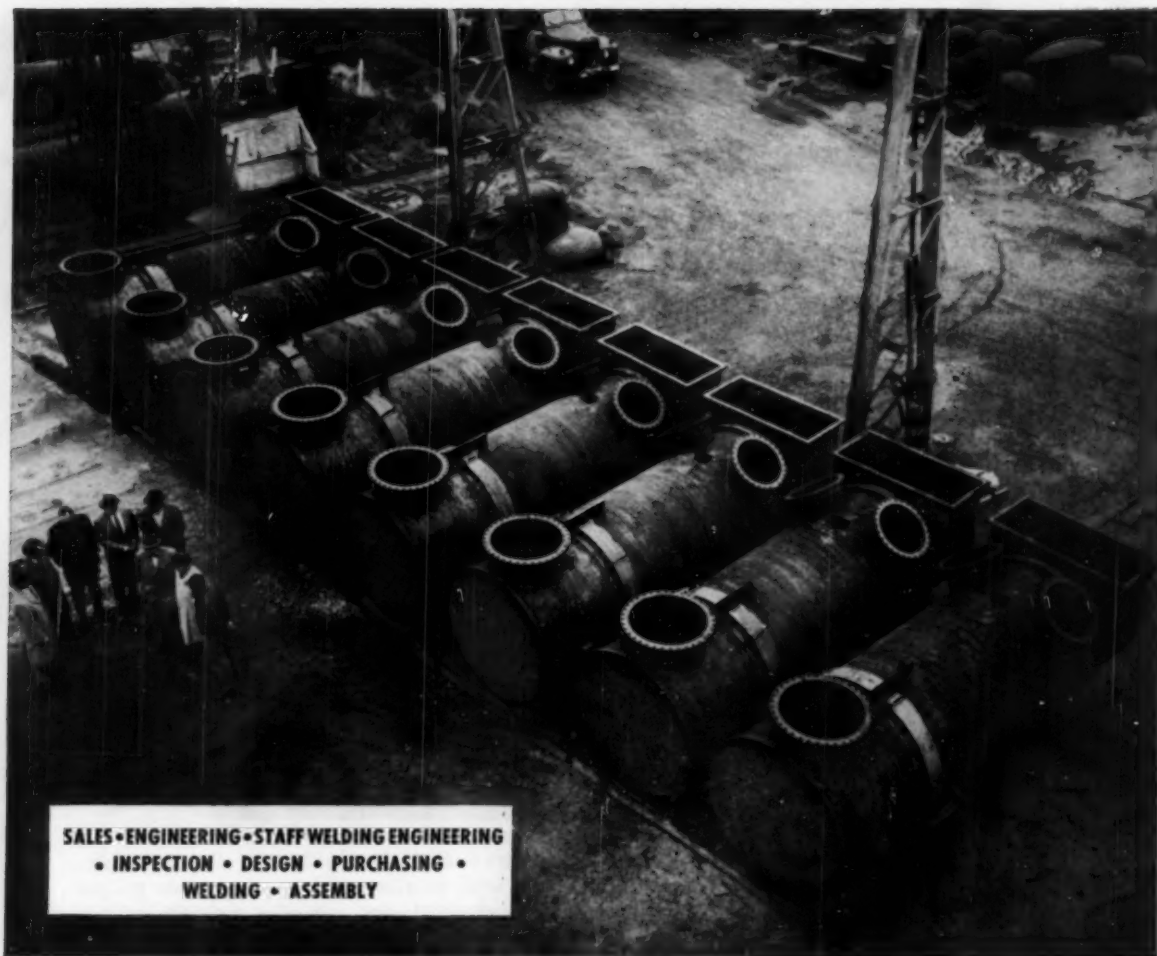
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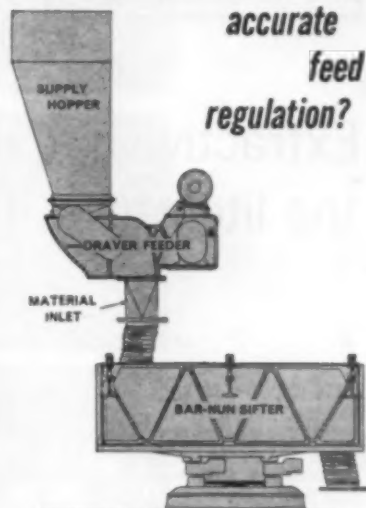
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## Extractive metallurgy, searching the literature, in new books

**EXTRACTIVE METALLURGY**, Joseph Newton, Professor of Metallurgy and Head, Department of Mining and Metallurgy, University of Idaho, John Wiley & Sons, Inc. New York, N. Y., (1959), 532 p., \$9.75

The viewpoint of the book is expressed in the first two paragraphs of the Preface:

"This book is essentially a revision and enlargement of the second part of my *Introduction to Metallurgy*, second edition. The scope and the arrangement of the material are much the same as they were in the earlier volume. In addition to the subjects conventionally covered in extractive metallurgy, there is included some discussion of metal crystals, equilibrium diagrams, and Gibbs' phase rule. These topics are normally discussed in courses on physical metallurgy, but

many students take extractive metallurgy before they take physical metallurgy, or students from other disciplines may elect to take only extractive metallurgy.

"As far as possible, the unit process method rather than a presentation of extractive metallurgy on a metal-by-metal basis is used. The aim is to discuss basic principles rather than detailed practice. Instructors can employ lectures and assigned reading to amplify the coverage in various areas."

One therefore might expect that the volume would embrace the philosophy of the unit operations of chemical engineering. Such, however, is not the case, and one is disappointed with the absence of treatment of material balances, thermal balances, and the like. Perhaps greater tabulation could have been employed

in connection with Chapter 1, particularly inasmuch as Table 3 on page 44 contains such a wealth of information and certainly emphasizes the relative importance in commerce of the various metals discussed in the book.

Chapter 2 on ore dressing is a review of current literature, with excellent condensation for the student. Chapter 3 is more elementary than it deserves to be and perhaps suffers by comparison with the excellent chapter on the structure of metals and alloys immediately following.

From here on one has the feeling that the volume rambles somewhat, in that better coordination could have been achieved. Chapter 8 on electrometallurgy suffers from lack of up-to-dateness and some sections are obsolete.

Over-all the book should be useful for students in extractive metallurgy, but does not have sufficient depth as a reference for the practicing chemical engineer or the mining and metallurgical engineer associated with extractive metallurgy industries. In the hands of an active professor in a school of metallurgy it should be an excellent guide and foundation for teaching the subject.

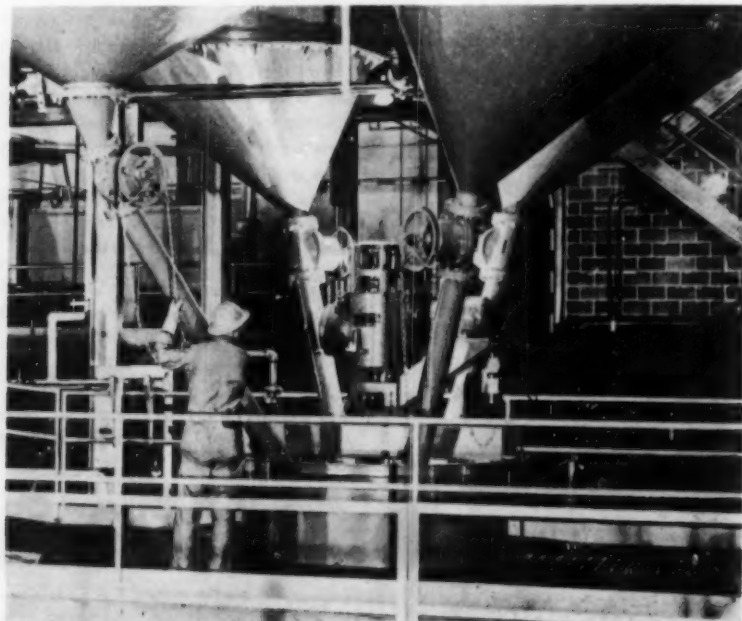
Reviewed by C. L. Mantell, Consulting Chemical Engineer, 457 Washington Street, New York 13, N. Y.

**A SHORT GUIDE TO CHEMICAL LITERATURE**, 2nd edition, G. Malcolm Dyson, Longmans Green and Co., (1959), 157 p., price \$3.25

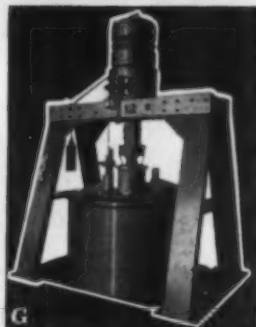
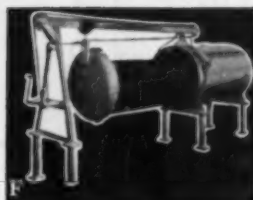
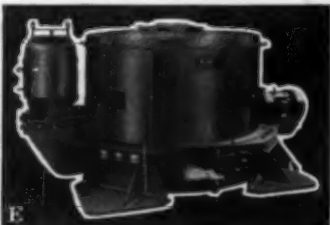
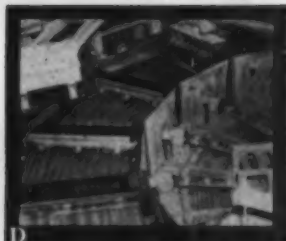
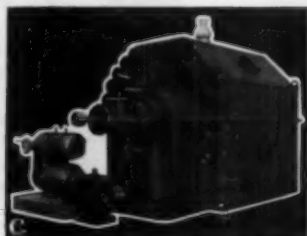
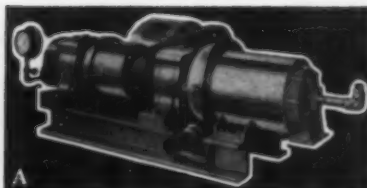
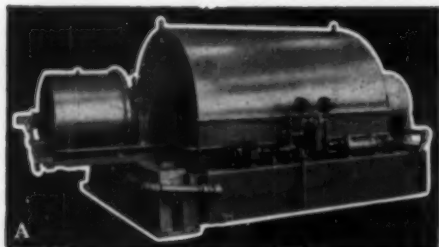
This little volume has been widely used since its first appearance in 1951. The timely second edition has been brought up to date by a rewrite of some of the sections of the first edition, and a general expansion of modern material throughout the text. As the author states in his preface, the book supplies an introduction to the literature of chemistry, and is therefore non-exhaustive in order to keep its price within the reach of all students of the subject.

The book's one hundred and fifty five pages are divided into seven chapters and three appendices, beginning with dictionaries and encyclopedias, and carrying on through chemical journals and periodicals, abstract journals, text books and special works of reference, works of reference on medicinal chemicals. The last chapter shows how to make a search of the literature.

It must be remembered that this is a British book, and hence omits a few  
*continued on page 8*







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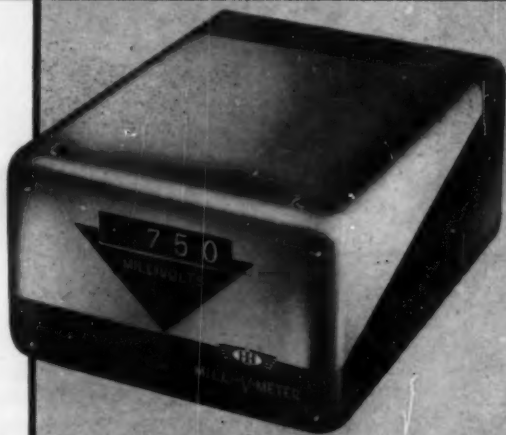
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## books

*from page 6*

American references which this reviewer considers important to a search. Again it is aimed at students of chemistry in which field it is much more complete than in the field of chemical engineering. There are a few references in Chapter 4 to applied chemistry and nuclear chemistry, but they could have been expanded to include other standard texts and the latest editions of some of the cited works which were available before this volume went to press. For instance, under petroleum the ASTM standard methods are cited, but the excellent British publication by the Institute of Petroleum is entirely omitted. Goldstein's first edition is mentioned, but not the second, and the very useful text by Keyes, Faith and Clarke is missing. The two supplements to the *Science of Petroleum* are also omitted.

Chapter five is unique in that chemistry cannot be divorced from medicine in the present. The chapter shows the many points which must be considered when searching a borderland subject, and may serve as a guide when searching other fields which touch on chemistry but have their own literature usually quite foreign to the chemist.

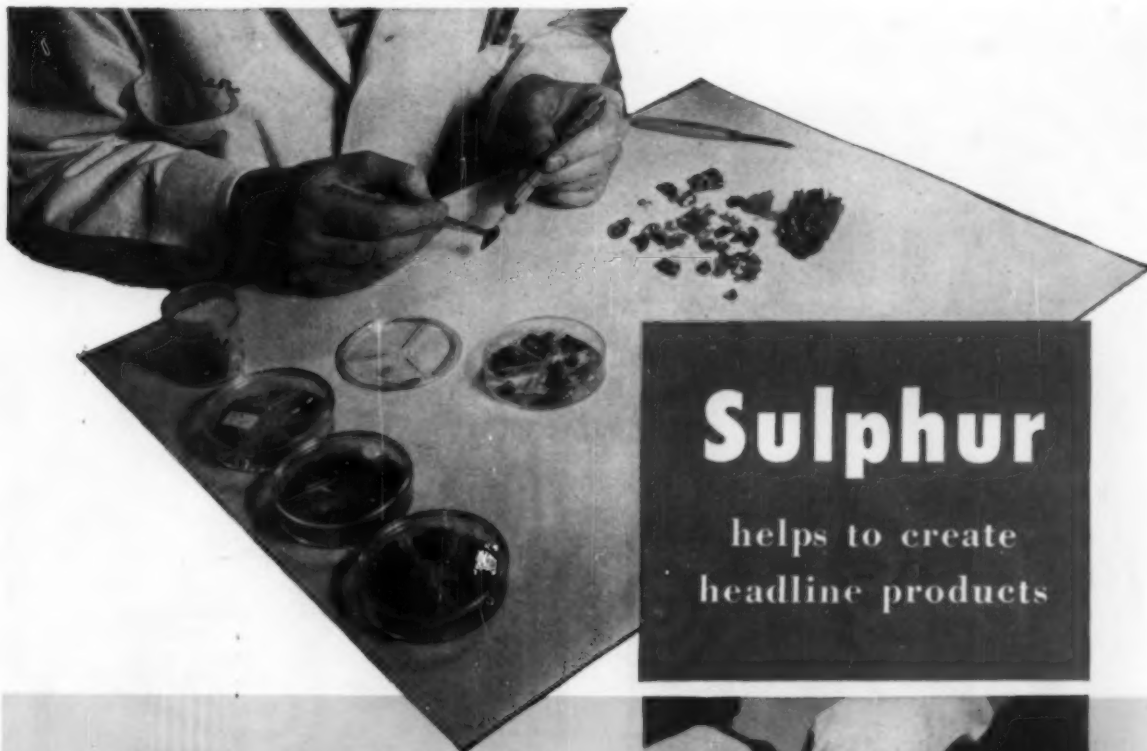
The appendices are both interesting and useful. Appendix I lists some old and obsolete journals. This section is particularly useful when tracking down obscure references in a basic search underlying a patent search.

Appendix II gives an additional example of an organic chemical search and is well worth studying as a guide to one's own efforts at a literature search.

Appendix III gives a listing of some sixty three journals from 1800 through 1956 with abbreviations and footnotes on many of the journals. This section has been extremely valuable to literature searching especially in the larger libraries where the cards in the index for the older volumes are under a different listing.

The volume is fairly free from typographical errors although there are a few. The text is well written, easily readable, and extremely well indexed according to author and subject. It should be a welcome addition to the libraries not only of students of chemical literature, but to those practicing chemists and chemical engineers who occasionally must make a literature search and are sometimes rusty on where to begin.

*Reviewed by Austin S. Brunjes, The Lummus Co., 385 Madison Ave., New York 17, N. Y.*

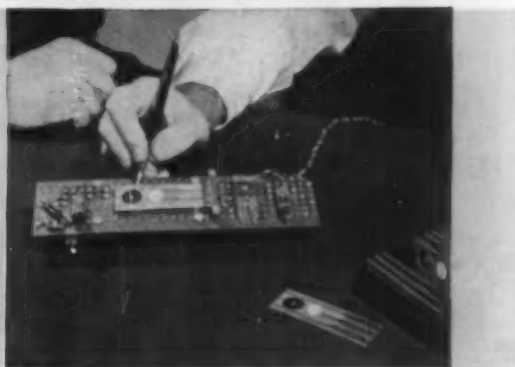


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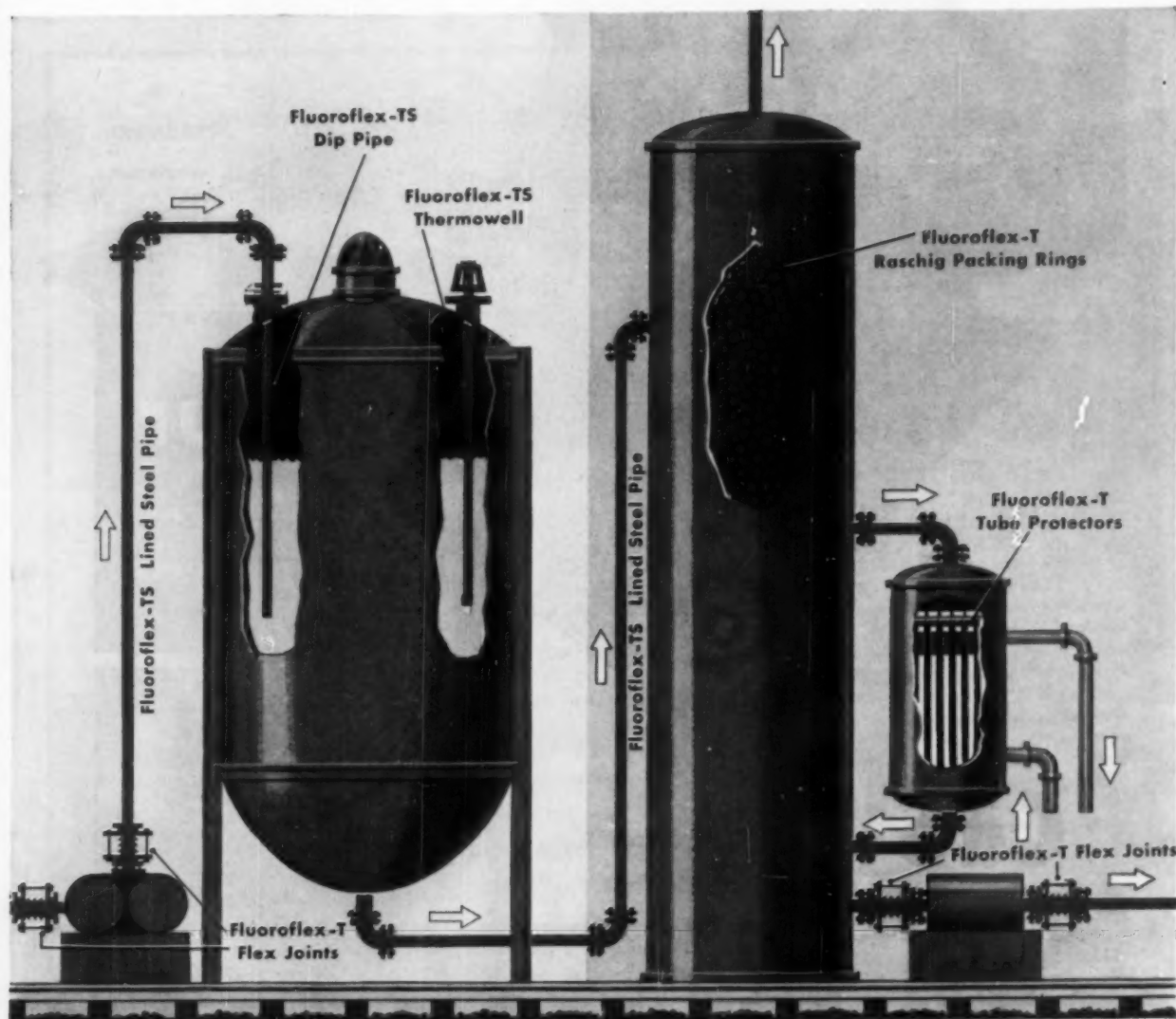


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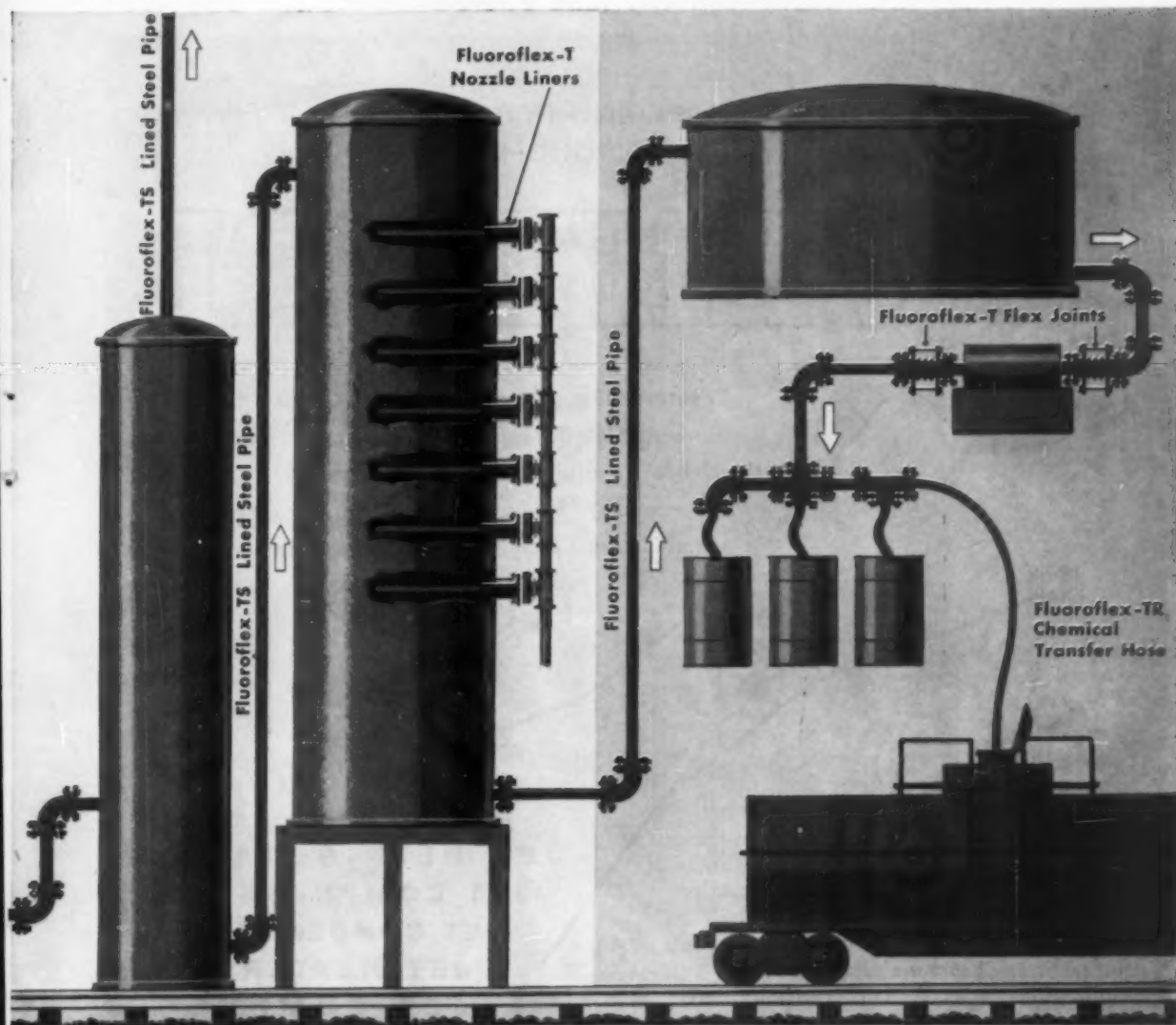
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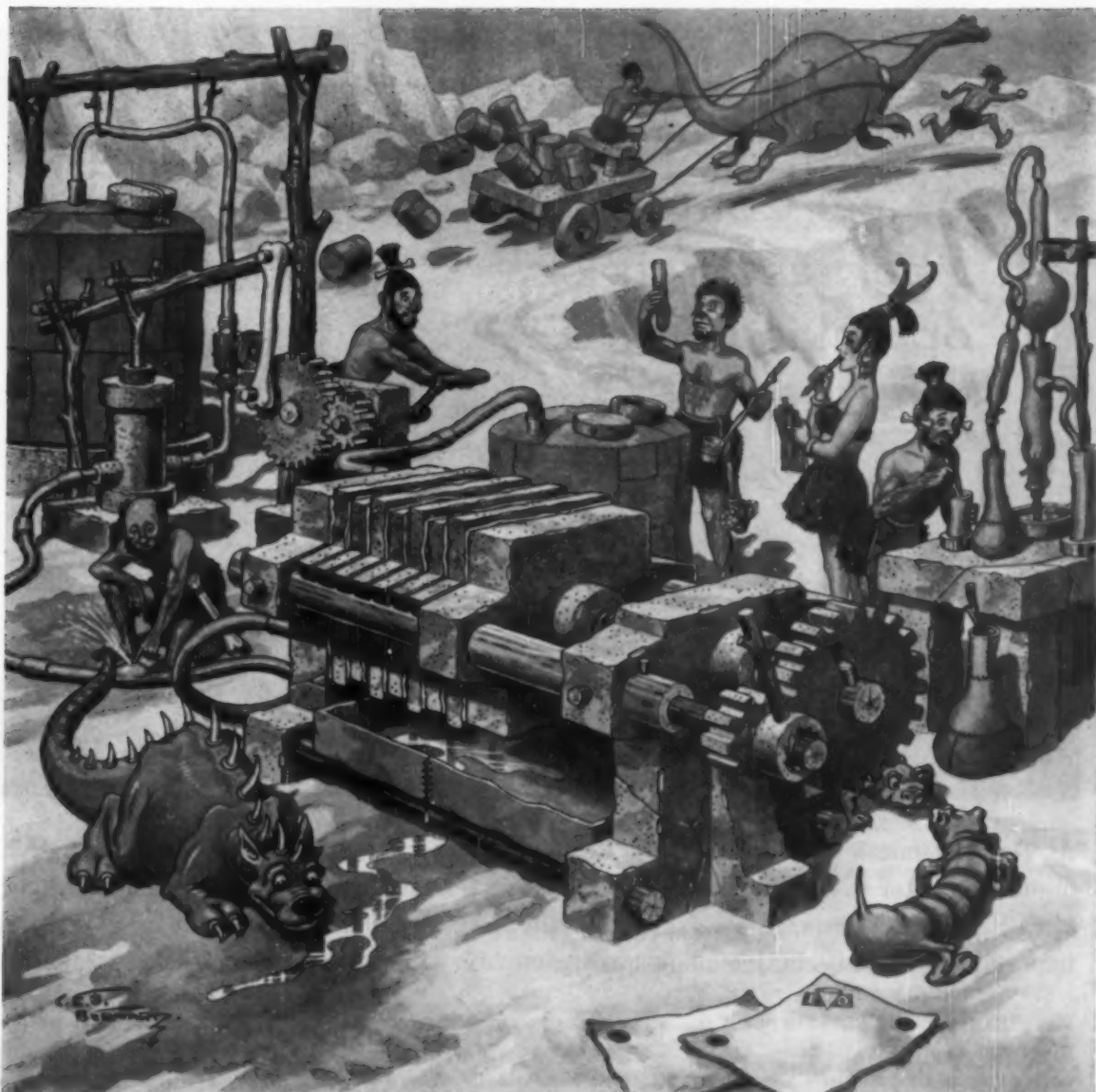


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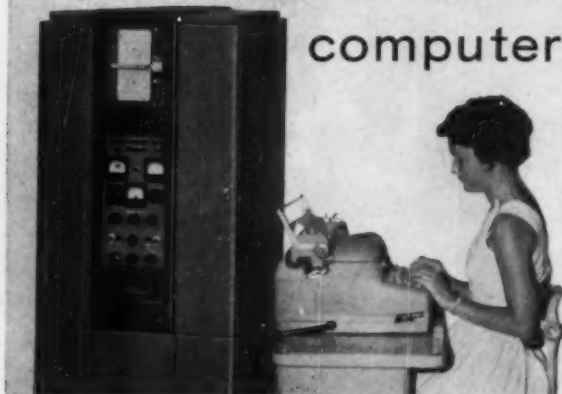
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computer



Herman P. Briar

At Dow Chemical, Research Project Leader Herman P. Briar used the Bendix G-15 digital computer to speed research and reduce material costs in the development of the new synthetic fiber, *Zefran*. The versatility of the low-cost G-15 also permits its usage on other important Dow projects, including quality control, engineering, and market development.

More than 350 G-15's are currently in use, many in the chemical process industries. One reason for this popularity is that the new user, through the G-15 EXCHANGE Organization, may take advantage of the work already done in applying the G-15 to his type of work. For instance, in the chemical field, the new G-15 user would have access to a wide variety of programs including:

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## New directions in management

Revised managerial climate needed in large industrial enterprises, says top Carbide executive at New York meeting of chemical engineers.

"I DO EXPRESS CONCERN over the growing notion that industry wants only conformists, and that large corporations are inert monsters that stifle individuality and initiative," said Howard S. Bunn, vice-chairman of the board of directors of Union Carbide, speaking at the September meeting of the New York Section of A.I.Ch.E. "I feel that nothing could be further from the needs of American industry," went on Bunn, "nor from the objectives of its top management."

Unfortunately, conceded Bunn, as organizations become larger and more complex, the tendencies toward conformity and submergence of the individual can become stronger. Where this happens however, he believes, it comes about largely because of apathy on the part of managers and subordinates alike, not through any conscious desire on the part of management.

### New horizons

Studies within Union Carbide, said Bunn, and those made in other companies, offer convincing evidence that a major part of the problem is related to the fact that in the last fifty years the composition of the human resources of industry has changed significantly, while our principles of motivation, human organization, and management have really changed very little. "The character of our jobs is changing rapidly. More and more of them are 'idea' jobs requiring restless inventive minds. Traditional management practices designed to deal with routine jobs and ordinary assembly lines seem to be neither appropriate nor effective for our present day situation. Organizational principles that are directed at narrowing and specializing all jobs do not meet our needs for breadth and flexibility."

Chemical engineers, emphasizes Bunn, can no longer be content with a narrow professional orientation, nor can engineering management afford to encourage such a viewpoint. He illustrates the present and growing importance of the chemical engineer in the management function by figures on their utilization within Union Carbide. As of mid-1960, there were 1,670 chemical engineers in Union Carbide—246 in engineering, 385 in research and development, 646 in production, 178 in sales, and 215 in other departments. Considering those who are responsible for the work of other people, calculates Bunn, 776 of these engineers, or 46.4%, are involved in the management of the corporation or its divisions.

The "mass points" of usage for chemical engineers have shifted, according to Bunn, from design to production, and from production to research and development. Forty-six percent of the chemical engineers hired at Union Carbide last year went into research and development. Only 29% were assigned to production, and 16% to engineering as such.

Industry, says Bunn, has traditionally tried to manage human resources by devising rules and regulations, and by imposing control by authority from the top downward through the organization. Good minds however, he believes, are not stimulated by dictatorial procedures, nor are they inspired by authoritarian managers. What is to be done to bring about a new managerial climate within large organizations?

### Credo

"I believe," says Bunn, "that people bring to an organization a

desire to achieve, to do a good job, and that, therefore, it is the responsibility of the manager to encourage and support the individual in his struggle for achievement.

"I believe that people work best when they have an objective which they have helped to formulate and identify. Therefore, I believe it is also the responsibility of the manager to have his people participate in setting realistic objectives for the functions he manages.

"I believe that the essence of communication is understanding, and that understanding is best achieved when everyone hears the complete story. When all the group understand the economics of the operation, the pressure for extra frills, services, and additional expense will subside.

"I believe that a man's interest in what he does has much to do with the caliber of his performance, and that, therefore, a young man coming into an organization should be exposed to more than one type of activity.

"I believe that both the individual's suggestions and small face-to-face discussions are vital ingredients of improving operations. I believe that such discussions are a vital part of the decision-making process, but that few decisions can or should be made by groups. I also believe, however, that individuals will make quicker and better decisions if they have the resources of the group behind them.

"I believe in leadership management—and this applies at all levels—president, works manager, laboratory group leader, district sales manager, or foreman. A good manager is neither a dictator nor an abdicator. He is an innovator . . . he is a communicator of information . . . he is objective in evaluating the performance of his people . . . in short, he takes the lead in creating a management climate in which growth, progress, and innovation can flourish." #

## Patents seen vital to research progress

**Merck president charges "piracy" by certain Italian pharmaceutical houses, U.S. Government abetment of the practice.**

"... IF THE PROTECTION of patents and trademarks were chiseled away, either here or in foreign countries, . . . the research boom itself would turn into a research bust," said John Connor, president of Merck, speaking recently at White Sulphur Springs to the Federal Wholesale Druggist's Assn.

Connor charged, in particular, that certain Italian pharmaceutical companies take advantage of loopholes in the Italian patent laws, copy new U. S. drugs, sometimes even before they are put on the market. They then sell them wherever they can get around the patent laws of other countries, undercutting U. S. prices, of course, because they have had to bear none of the original research and development expense. "Let us call this by its right name", said Connor. "It is piracy, pure and simple."

Connor charged further that the U. S. Government recently started buying drugs that were discovered and patented in the United States from the Italian manufacturers who copied them, thus aiding and abetting this "piracy" and undercutting American research.

### The industry of discovery

Connor credited the American system of research and development with being the mainspring of our expanding economy. In support of this position, he quoted the late Sumner Slichter, economist, "The discovery that an enormous amount of research can be carried on for profit is surely one of the most revolutionary economic discoveries of the last century."

In 1939, according to Connor, we spent only half a billion dollars on research and development. By 1946, the figure had reached \$2.1 billion, by 1953 it stood at \$4.9 billion. Since then the rate has been "explosive," and it has been estimated that the \$12 billion mark was passed last year. Connor points out that what was once the province of the lonely inventor has become what amounts to "an assembly line for the planned production of discoveries." Some of the new products and new materials from this

assembly line have already reached the market place. But the real flood, thinks Connor, is expected later in the sixties. "When it comes," he predicts, "its impact on our already bustling economy may be as great as the impact James Watt's steam engine had on the quiet country towns of eighteenth century England."

By 1970, according to Connor, the enormous expansion in industrial research will lift the U. S. economy to \$750 billion, 50% higher than today's. #

### Atomic energy program seen vital to U.S. prestige

Eighty-four percent of the public believes that the development of peaceful uses for atomic energy is important to the world-wide prestige of the United States, according to the findings of a survey conducted on behalf of General Electric. Sidelight—while fully 70% of the people queried feel that the stock of companies in the atomic area is a good investment, only half this number were able to name even one company in the field.

### U.S. principle contributor to UN technical assistance program

The United States will contribute an estimated \$14 million in 1960 to the United Nations Technical Assistance Program. Runnerup is the United Kingdom with \$3 million, in third place is Canada with \$2 million. However, on a per capita basis, leading contributors are Norway, Denmark, and Sweden, in that order.

### Ground broken for sea water conversion plant

The first of five experimental sea water conversion plants authorized by the Federal Government is officially under construction at Freeport, Texas. Builder is Chicago Bridge and Iron, system is multistage evaporation. Gulf water will be converted to serve residents of Freeport and two nearby Dow Chemical plants. Design capacity of the installation is 1 million gallons per day.



## Innovators versus imitators

Mutual fund dealers hear Du Pont analyst tell "how to pick the winners" among chemical company investments, show the growth pattern of the chemical industry.

"INNOVATORS" ARE A BETTER investment bet than "imitators," Chaplin Tyler of Du Pont told the recent National Mutual Fund Dealers' Conference in Washington, D. C. The statement was based on an analysis in which 24 companies in the chemical and allied products industry were divided into two groups of 12 each, one group being classed arbitrarily as innovators, the other as imitators. For 1959, the "innovator" group earned a net return of 7% on average gross capital, twice the return earned by the "imitators."

The comparison was then restricted to four companies, all among the largest in the industry. Two were classed as innovators, two as imitators. Again net return on average capital employed was twice as much for innovators as for the imitators (8% in 1959). Moreover, said Tyler, the average research expenditure as a percentage of sales was twice as much, roughly 3%, for the innovators as for the imitators.

### Growth rate seen steady

But innovator or imitator, the future looks bright for the entire industry. "Projection of output for the chemicals and allied industries at an average rate of 7% seems logical," said Tyler, going on to point out that would mean over \$50 billion sales in 1970 compared to an estimated \$28 billion for 1960, assuming no change in the price index. This is approximately double the postwar growth rate for all U. S. industry (about 3%).

Growth rates of 10% or more have

been reported for "chemical industry," admits Tyler, but such rates, he points out, usually refer to particular product groups or segments, not to the entire industry. For example, during the postwar period, rate for "industrial chemicals" was 10%, for "plastic materials" 17%. Then, too, price inflation may result in apparent high growth rates. Thus, from 1940 to 1951, sales of chemicals and allied products increased at an average annual rate of 13%. However, about half the dollar increase was caused by price inflation.

### How firm a foundation

The case for continued growth, however, rests on much firmer ground than statistical inference, insists Tyler. Both past performance and future indications derive from the particular inherent characteristics of the industry itself. Because the material demands of our society are continually increasing in variety and quantity, the least growth that

the chemical industry can expect is the growth rate for all industrial production. Thus, concludes Tyler, "chemical growth has a floor but no ceiling."

### Increasing competition

Look for ever increasing competition, both from within the industry and from without, Tyler told the assembled mutual fund dealers. To illustrate the magnitude of "outside" competition, he pointed out that sales of chemicals by one oil company last year were big enough to put it among the ten largest chemical enterprises in the nation. As a second example, when Du Pont built the first large-scale urea plant some 30 years ago, the project was considered more or less unique. Today, there are 13 U. S. producers, and five different processes available for license. Among the 13 producers are two oil companies, a shipping and banking enterprise, an agricultural equipment manufacturer, and a farm cooperative. #

### Engineer, scientist demand drops slightly

Demand for engineers and scientists, which dropped sharply in June of this year and again in July, continued to drop in August, according to an "Engineer/Scientist Demand Index" compiled by Deutch & Shea, New York advertising firm. The drop in August, however, was considerably less sharp than in the preceding summer months. A combined index figure, incorporating statistical data from both technical journals and newspapers in key industrial centers, shows a drop of only 2.4 below July's base figure of 100, says Deutch & Shea. A reversal of the downward trend is expected for September, traditionally a period of increased recruiting activity by industry.



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18 October 1960

For more information, circle No. 118 ➤

CHEMICAL ENGINEERING PROGRESS, (Vol. 54, No. 10)

# U.S.I. CHEMICAL NEWS

October

★

A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries

★

1960

## National Distillers Joins Shell International in Polyolefin Venture Abroad

A joint company has been formed by Shell International Chemical Company Ltd., London, and U.S.I.'s parent company, National Distillers, to develop plans for production and marketing of polyolefin film and packaging materials outside the U.S. and Canada. The new company operates from London.

National Distillers is one of the world's largest producers of polyethylene and owns the Kordite Company—a leading manufacturer in the U.S. of plastic film and packaging. It has recently set up a company in Switzerland to cover sales and development of polyethylene.

## New Direct Halogenation Process Converts Impure Metal to Purified Halide

A safe and commercially adaptable process for the direct halogenation of crude metals—to obtain the corresponding halide substantially free of certain undesirable metal impurities—is covered in a patent recently issued to U.S.I.'s parent company, National Distillers. Metal halides which can be prepared by this process are those of the reactive metals such as titanium, zirconium, hafnium, columbium and tantalum.

As described in the patent, an impure feed such as scrap zirconium is safely reacted with a halogen gas by diluting the latter with an explosion-preventing proportion of helium, argon or neon. The reaction is carried out at 450°-900°C until 50-90% of the feed has been reacted. A metal halide is recovered which is considerably lower in metal impurity content than the original scrap feed. A typical analysis of  $ZrCl_4$  prepared by this process is given in the following table:

COMPARATIVE METAL IMPURITY CONTENTS—METAL FEED VERSUS HALIDE PRODUCT

Metal Impurity	Low Hafnium Zirconium Scrap Feed*	$ZrCl_4$ Product*
Al	65	94
Cd	< 0.5	0.8
Cr	700	35
Fe	970	140
Mn	23	< 5
Ni	255	< 15
Pb	85	20
Sn	1.6%	168
Ti	< 20	< 20
U	< 10	< 10
W	< 20	< 20

\* Values in ppm based on zirconium unless otherwise stated

## Ammonia Production, Storage Capacity Expanded by U.S.I.

### Refrigerated, Non-Pressurized Storage Tank to be Installed

Ammonia production capacity has been increased by 17%, and anhydrous ammonia storage capacity will soon be expanded by U.S.I. at its Tuscola, Illinois, plant. The plant is already operating at the expanded rate of 70,000

tons per year (up from 60,000 tons) and a new 6,000-ton storage facility is expected to be in full service by the end of the year.

This increased production and storage capacity are needed to assure rapid delivery to U.S.I.'s ammonia, aqua ammonia and nitrogen solutions customers, especially during the heavy seasonal demand in early spring. Because of the plant's location in Central Illinois, heart of the Midwestern fertilizer industry, most of its output is used as a raw material in this highly seasonal business. Other applications for U.S.I. ammonia include chemical processing, refrigeration and miscellaneous industrial uses.

### Storage Tank Uses New Principle

The new 6,000-ton storage tank will use the relatively new principle of storing refrigerated ammonia at atmospheric pressure, rather than storing in pressurized tanks at moderate temperatures. The storage vessel consists of an inner tank, 88 feet in diameter and 56 feet high, separated from an outer tank by 2½ feet of insulation. Liquid ammonia is stored in the tank at a temperature of about -28°F, and this low temperature is maintained by evaporation of ammonia from the surface.

The evaporated ammonia is recompressed, condensed and returned to the tank. It can also be used as feed stock for the adjoining ammonium nitrate plant.

## Polyethylene — Aggregate Forms New Paving Material



A new paving material compounded of pigmented polyethylene and aggregate promises to bring color-coding of roads and runways closer to reality. It can be mixed and applied (in a one-inch layer) using conventional machinery and methods. Brilliant white test curbing, shown being installed in the photo above, defines road boundaries. Other possible uses include multi-colored home driveways, tennis courts, sidewalks, swimming pools.

## New TVA Process Uses Wet-Process Phosphoric to Make Diammonium Phosphate

TVA engineers are developing a new process to make granular diammonium phosphate fertilizer. It is reported that the method can use low-cost wet-process phosphoric acid without a purification step.

By taking advantage of chemical heat in the reaction of acid and ammonia, recycle rates and drying requirements are reduced below those of some competitive processes, according to TVA. Grade of product depends on purity of phosphoric acid available, and ranges up to 21-53-0. The process is being adapted to production of various grades, some containing potash.

TVA claims that its ammoniator is the key equipment in the process. Wet-process phosphoric acid, such as that made by U.S.I. at Tuscola, Illinois, is partially

MORE

## New Type of Carbon Black Obtained from Burning Hydrocarbons in Chlorine

Researchers have obtained high yields of carbon blacks containing chemically bonded chlorine, by burning various hydrocarbons in the halogen gas rather than in oxygen. Such chlorocarbon blacks may have commercial use in rubber and plastics compounding, according to a recent report.

In the study, methane, propane, ethylene and natural gas were burned with submaximal amounts of chlorine to yield carbon black as a major product. By

MORE

October

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# U.S.I. CHEMICAL NEWS

★

1960

## CONTINUED

## TVA Process

preneutralized in a tank. Then the ammoniation to diammonium phosphate is completed in the ammoniator-granulator drum. Excess ammonia must be fed to the drum to produce diammonium phosphate. Therefore, a scrubber is required to recover ammonia from exhaust gases. Phosphoric acid is fed to the scrubber to absorb ammonia, and the solution is fed to the preneutralizer. A recycle ratio of about 3:1 is required for control of granulation. Physical properties of the closely sized granular product are said to be excellent.

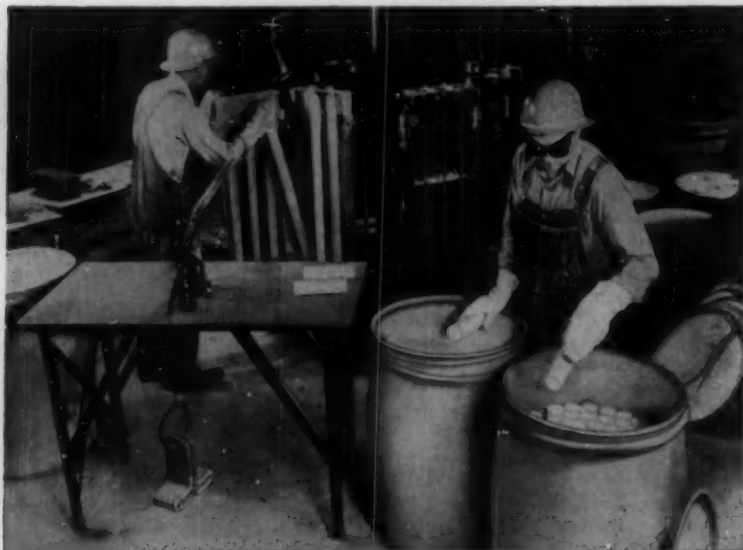
## CONTINUED

## Chlorocarbon Blacks

contrast, carbon black is only a by-product when these hydrocarbons are burned with oxygen. The quantity of carbon produced in the chlorine-hydrocarbon flames seems to be directly proportional to the chlorine-hydrocarbon ratio. It also seems to depend on the hydrocarbon used, and is greatest for methane.

These carbon blacks can contain as much as 45% chlorine. The halogen appears to be bonded to the carbon chemically, researchers report, since all attempts to remove it have left at least 10% chlorine.

## No Oil for Sodium Bricks



Sodium packed under kerosene? Perhaps in the laboratory but not in industry, as you can see from this photo of the cutting and packing operations at U.S.I.'s metallic sodium plant in Ashtabula, Ohio. Every year, many tons of sodium are molded into bricks and packed dry in steel drums. An airtight seal is maintained during storage and shipment.

All phases of sodium handling are discussed in the latest edition of U.S.I.'s brochure "Handling Metallic Sodium on a Plant Scale". For your copy, address Technical Literature Department, U.S.I. Chemical News, 99 Park Avenue, New York 16, New York.

## TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

Chlorine safety data sheet is now being sold by MCA for nominal price. Covers properties, hazards and their engineering control, employee safety, emergency measures, container handling, waste disposal, medical management. No. 1840

New group of urethane elastomers now offered for use where abrasion resistance is essential. Claimed more rugged than manganese steel and other metals. Suggested for chute linings, pipeline crawler wheels, scrapers, etc. No. 1841

Temperature-indicating crayons and paints now on market are said to check temperatures of hot surfaces by completely changing color. Series of products cover range from 104°F. to 2,462°F. Claimed easy to apply and remove. No. 1842

Sodium peroxide is covered in new data sheet giving specifications, typical analysis, properties, shipping data and uses. Technical service is offered on handling and use in pulp and paper, textile and other fields. No. 1843

New laboratory oven is said to give highest temperature, combined with vacuum, now available. Can heat from room temperature to 500°F. in one hour, in 11-inch diameter by 12-inch deep vacuum chamber. No. 1844

Dry sulfamic acid product—with built-in pH color indicator, corrosion inhibitors, anti-foams, wetting agents—can now be obtained for removal of lime scale deposits from evaporator condensers and cooling tower systems. No. 1845

Polyethylene waste and drainage system described in new engineering and parts catalog now available. Said to be complete, permanent, corrosion-resistant. Includes sinks, traps, pipe and fittings, adapters, other equipment. No. 1846

Concise conversion tables and circular slide rule, now offered for chemical engineers, is shirt-pocket size. Includes slide rule, table of elements, temperature conversion chart, conversion factors, useful constants and data. No. 1847

m-Sulfobenzic acid—new intermediate for dyes, colors, color developers and couplers, surfactants, textile treating agents, flavors, drugs, preservatives, dehydrating agents—is subject of data sheet recently released. No. 1848

Fallout is subject of new book which can now be purchased. Book covers bomb types, meteorological dispersion and persistence of fallout, effects of radiation, radiation sickness, biological effects, nuclear war, civil defense. No. 1849

## PRODUCTS OF U.S.I.

**Heavy Chemicals:** Anhydrous Ammonia, Ammonium Nitrate, Nitric Acid, Nitrogen Fertilizer Solutions, Phosphatic Fertilizer Solution, Sulfuric Acid, Caustic Soda, Chlorine, Metallic Sodium, Sodium Peroxide.

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## New Light on a Compound Semiconductor

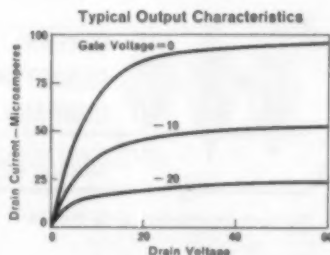
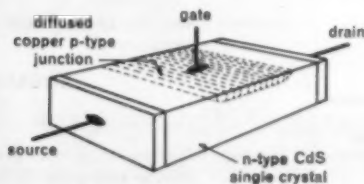
Pictured is a new and unusual transistor . . . made from a *compound* semiconductor. Its electronic properties are greatly affected by *light*. It is a *field-effect* transistor having input impedances up to 100 megohms (versus 1,000 ohms for junction transistors). Its unique combination of properties has enabled it to perform some novel circuit functions not possible with other transistors.

Still in the early experimental stage, this phototransistor is a tangible result of the General Motors Research Laboratories' program on semiconductors — particularly the group II-VI compound, cadmium sulfide. Behind its development lies the steady accumulation of (1) know-how in crystal growing, doping, and contact preparation and (2) information about CdS's intriguing solid state properties (red or green luminescence, high photoconductivity, short relaxation times, etc.).

For the researcher, this three-terminal device is adding a new dimension to the fundamental understanding of semiconductors. For instance: GM Research scientists have uncovered the important role of photo-generated holes in modulating the conductance of this intrinsic semiconductor and have determined the hole drift mobility through a new theoretical analysis.

These semiconductor investigations illustrate the dual aim of GM Research: contributions to the science, advances in the technology of important new subject areas. Such research is the initial step in General Motors' continuing quest for "more and better things for more people."

### General Motors Research Laboratories Warren, Michigan

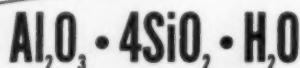


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- Parting Agent
- Coating Agent
- Bleaching of chemicals, animal, mineral & vegetable oils
- Filter Agent
- Absorbent for liquids, chemicals, greases, oils

#### Approximate chemical analysis

Loss @ 105°C.	0.60%
Further Loss on Ignition	3.25%
Silica (SiO <sub>2</sub> )	73.77%
Alumina (Al <sub>2</sub> O <sub>3</sub> )	12.66%
Ferric Oxide (Fe <sub>2</sub> O <sub>3</sub> )	4.16%
Magnesia (MgO)	3.80%
Calcium Oxide (CaO)	0.34%
Ferrous Oxide (FeO)	0.08%
Sodium Oxide (Na <sub>2</sub> O)	0.04%
Potassium Oxide (K <sub>2</sub> O)	0.09%
Titanium Dioxide (TiO <sub>2</sub> )	0.79%
Arsenic Oxide (As <sub>2</sub> O <sub>3</sub> )	0.00056%
Mercuric Oxide (HgO)	Less than 0.00005%*
Lead Dioxide (PbO <sub>2</sub> )	Less than 0.00007%*
	Less as lead dioxide
Phosphorus Pentoxide (P <sub>2</sub> O <sub>5</sub> )	0.22%
Sulfate (SO <sub>4</sub> )	0.17%
pH around 5	

\*None found.

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## Washington scope

### Chemical industry abroad

World-wide foreign investments of the chemical industry, in 1959, exclusive of the petrochemical industry, amounted to \$1.657 billion. This represents a substantial increase over previous years. Typical figures:

1950 \$512 million  
1957 \$1378 million  
1959 \$1657 million

This increase of almost \$300 million in 1959 over 1957 compares to an increase of total U. S. foreign investments in manufacturing plants (exclusive of the petrochemical industry) of 1.7 billion dollars.

More complete data covering U. S. foreign investments in plant and equipment, which will further point up the tendency of the chemical industry to hedge against rising production costs in the USA are now being compiled by the appropriate Government agencies.

Last March, this column reported that foreign competition was a "touchy" subject in Washington. It's somewhat more sensitive now, but there seems to be no question about the trend that the chemical industry, and all industry, is following to solve

the problem of meeting the lower costs of foreign producers.

There's no question about the fact that leaders of industry and Government alike would much prefer to see all of these American dollars stay right here in the USA. To have all production facilities established on American soil helps the tax situation, the unemployment situation, and contributes greatly to the peace of mind of the planners for national security.

However, all elements of our nation seem to thoroughly understand the necessity of winning the cold war economically rather than resorting to armed conflict. Hence, no highly organized group or really effective "movement" seems likely to stay the chosen national policy of exporting equipment, know-how, capital, and jobs abroad.

Quite to the contrary, all of our efforts to catalyze the building of a large foreign-based American chemical industry seem to be generally applauded throughout the nation even though foreign aid programs are generally fiercely debated. Look, for ex-

*continued on page 26*

#### EXPORT-IMPORT BANK (EXIMBANK)

	DOLLARS	FOREIGN CURRENCIES (COOLEY LOANS)
<b>Purpose</b>	Assist in financing and facilitate U. S. imports and exports	Assist foreign economic development and expansion of markets for U. S. surplus agricultural commodities

#### DEVELOPMENT LOAN FUND (DLF)

	DOLLARS	FOREIGN CURRENCIES
<b>Purpose</b>	Aid in developing economic resources and productive capabilities of less developed countries	

#### INTERNATIONAL COOPERATION (1) ADMINISTRATION (ICA)

	FOREIGN CURRENCIES	INVESTMENT GUARANTIES
<b>Purpose</b>	Encourage multi-lateral trade and economic development	Encourage and facilitate U. S. private investment in under-developed countries, in equity loans and licensing arrangements

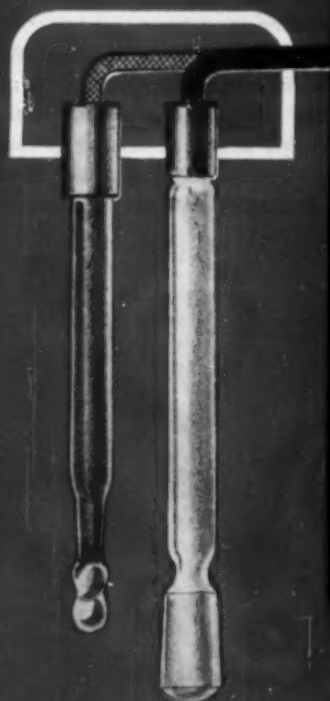
#### INTERNATIONAL BANK (2) (IBRD)

	CURRENCIES OF MEMBER COUNTRIES, PRINCIPALLY DOLLARS
<b>Purpose</b>	Aid the development of productive facilities and resources in member countries

#### INTERNATIONAL FINANCE CORP. (IFC)

	DOLLARS
<b>Purpose</b>	Further economic development by encouraging growth of productive private enterprise in member countries, especially in less developed areas





Foxboro pH Dynalog Recorder has an input impedance of 80,000 megohms — eliminates the need for intermediate amplification. Span is adjustable from 2-12 pH; zero, from 0-12 pH.

**NEW!**

## Foxboro eliminates the amplifier from pH recording and control

cuts the drift, cuts the cost, cuts the maintenance, too!



Foxboro pH Dynalog Controller — for use where it is desired to hold pH at a predetermined value.



Foxboro pH Dynalog Indicator — for use where complete record of pH value is not required.

THAT'S RIGHT — the intermediate amplifier is gone from Foxboro's new low-cost system for measuring pH. And gone with it is the wasted panel space, the drift, the daily standardization inherent with earlier systems.

In the new Foxboro system, the signal from the pH electrode goes direct to a high impedance Dynalog\* receiver — without intermediate amplification. Signal operates a direct-reading indicator or recorder — or a controller and alarms, when desired.

The new Foxboro pH system is the simplest, most economical method of measuring pH available today. Ask your Foxboro Field Engineer to tell you about it. Or write for data sheet. The Foxboro Company, 9310 Neponset Avenue, Foxboro, Massachusetts.

\*Reg. U.S. Pat. Off.

# FOXBORO Analytical Instrumentation

REG. U.S. PAT. OFF.

For more information, turn to Data Service card, Circle No. 85

## NEW P-K HEAT EXCHANGER MANUAL SIMPLIFIES SELECTING COMPONENTS FOR INSTALLATIONS LIKE THIS

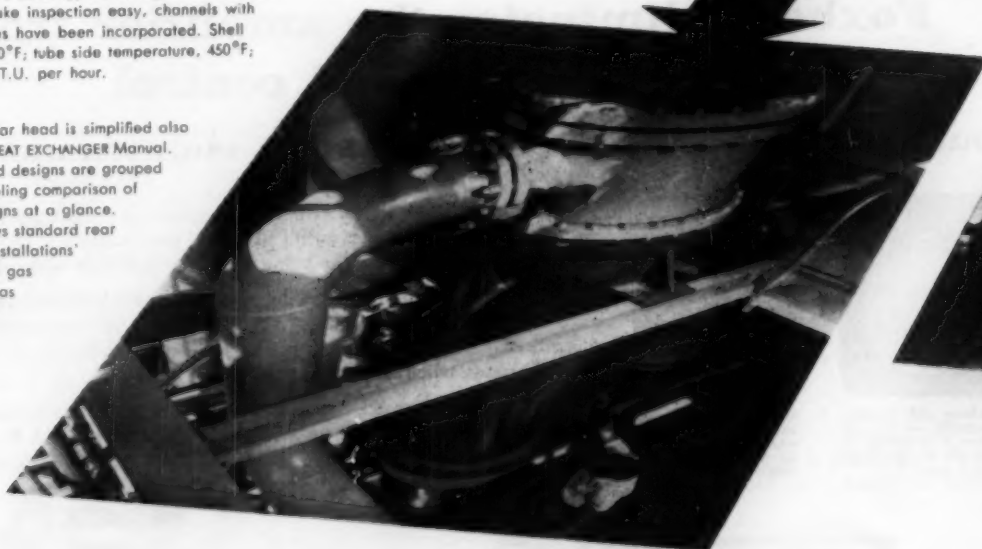
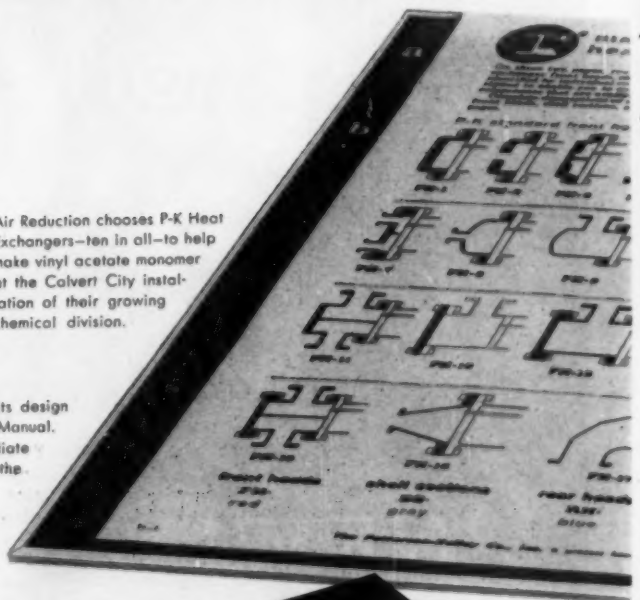


Air Reduction chooses P-K Heat Exchangers—ten in all—to help make vinyl acetate monomer at the Calvert City installation of their growing chemical division.

① Which type front head for your heat exchanger? You can "pinpoint" its design more quickly by reference to the head coding index in the new P-K HEAT EXCHANGER Manual. In the Air Reduction installation four P-K exchangers of the type at the immediate right cool crude product gas in the tube side by means of water flow through the shell side. Tube temperature is 300°F; shell temperature 150°F; capacity, 581,000 B.T.U. per hour.

② Shell sections, such as the one at right center, can be surveyed and specified more easily by reference to the standard shell section designs grouped and coded in the P-K HEAT EXCHANGER Manual. There are four units like that at the Air Reduction installation, a straight tube, fixed tube sheet type exchanger with integral expansion joint. To make inspection easy, channels with removable cover plates have been incorporated. Shell side temperature is 300°F; tube side temperature, 450°F; capacity is 580,000 B.T.U. per hour.

③ Selection of rear head is simplified also when you use the P-K HEAT EXCHANGER Manual. Twenty-eight rear head designs are grouped and coded here, enabling comparison of the most popular designs at a glance. Photo at far right shows standard rear head on one of the installations' two refrigerated type gas cooler and liquid-to-gas heat exchangers.



plifying the underlying details of design.

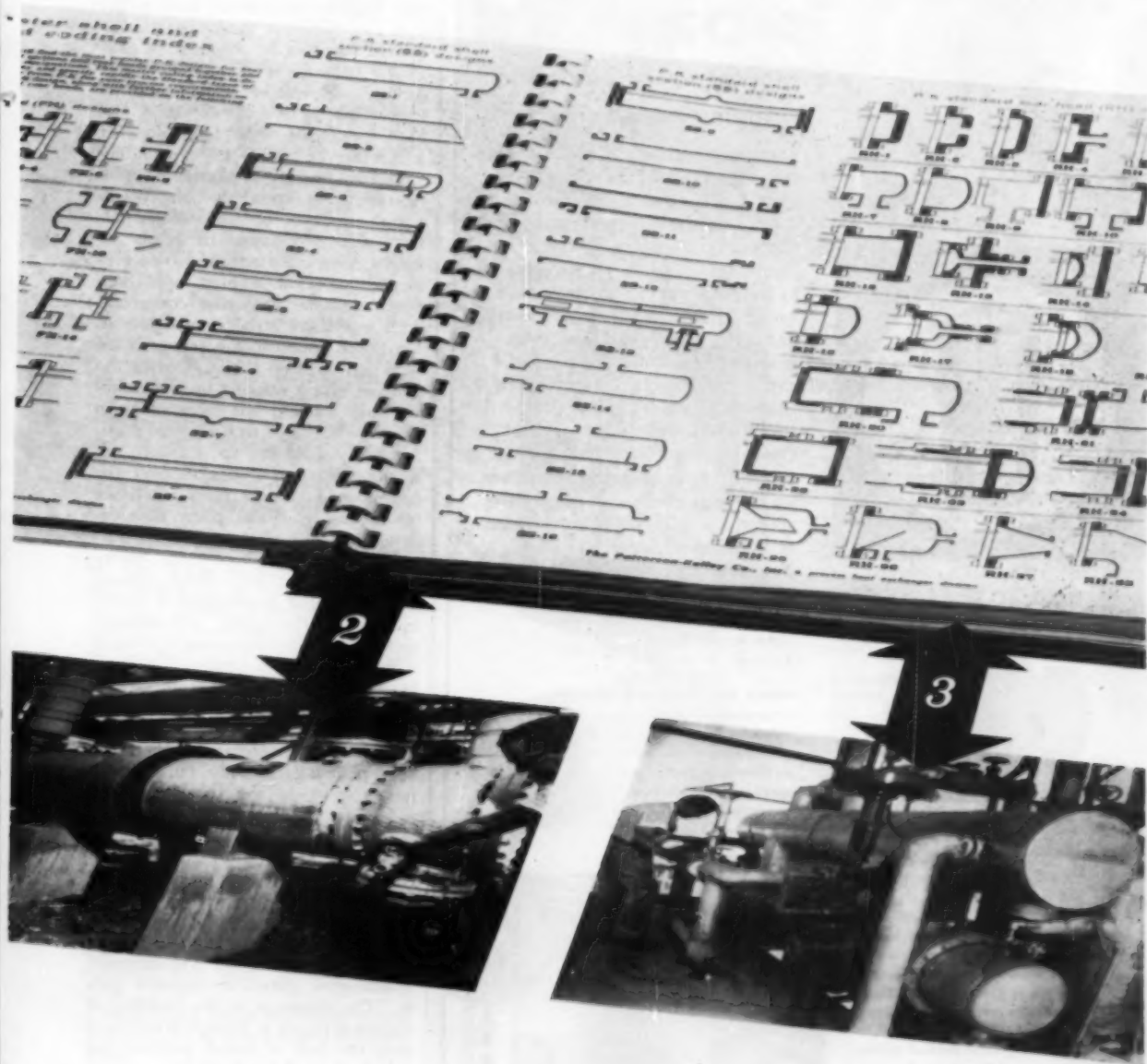
In other sections of the P-K HEAT EXCHANGER Manual you find an outline of the economic and performance advantages of principal designs, a review of the fundamentals of heat transfer, and a number of basic tables and formulas, along with a comprehensive design check list and other features.

As significant developments occur, the P-K HEAT EXCHANGER Manual will be supplemented and the new material sent to registered holders.

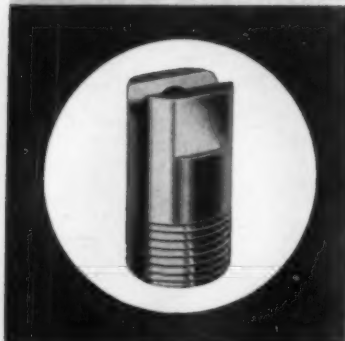
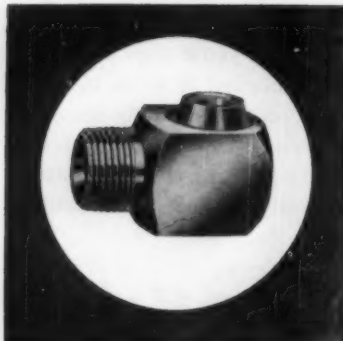
Available copies of this useful new manual are limited in number, and therefore are reserved pri-

marily for those in the process industries who can best apply the information. If you design or specify heat exchangers, you are invited to write to us on your company letterhead, outlining briefly the areas of your interest. A few copies are available to students and non-technical personnel at a nominal charge. The Patterson-Kelley Co., Inc., 990 Burson Street, East Stroudsburg, Pa.

**Patterson Kelley**  
Heat Exchanger Division



For more information, turn to Data Service card, circle No. 45



Continuing research is the key to Spraying Systems' product leadership . . . research in new spray nozzle designs and materials to achieve better performance . . . and research in manufacturing methods to give you ever greater product quality at lowest possible cost.

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corrosive liquids or gases  
you have the choice of*

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plete technical information  
on thousands of standard  
spray nozzle types and  
capacities.



SPRAYING SYSTEMS CO. THEORETICAL  
AND APPLIED RESEARCH LABORATORY

## Washington

*from page 22*

ample, at the banks that have been set up at least in part at tax-payer's expense—yet not one business executive in a hundred understands the source of funds or the function of each. They simply know that these tax supported organizations catalyze, in some way, the participation of U. S. industry in foreign business.

Now another newly organized international bank designed to make investments in Latin America will open in Washington October 3rd, the first business day of that month. This new financial institution, Inter-American Development Bank, headed by Philippe Herrera as president, is controlled by seven directors. The Inter-American Development Bank had its conception in August of 1958. Its basic principals were formulated at a meeting of the O.A.S. (including Cuba) in January to March of 1959. According to knowledgeable Washington students of international affairs, this new source of funds for Latin American industrial developments comes at a most opportune time. As one engineer conversant with world industrial trends puts it, "In South America, the Japanese are working on the Pacific Coast, the Europeans are working on the Atlantic Coast, and by the terminology in the translations of technological documents, I would say the Russians are working through fronts all over the continent. In a few years you'll see astonishing chemical plant developments in South America."

Washington sources tell pretty much the same story about Africa—great potential petrochemical developments in the north; consequential metallurgical developments in Central Africa; synthetic organic and inorganic chemical expansion in South Africa.

It's difficult to name a consequential U. S. chemical company or process equipment manufacturer that is not now planning, actually building, or participating in the construction of a foreign chemical plant somewhere in the world. While the long-range results on U. S. prosperity and security may be questionable, there seems to be no question about the continuing acceleration of the rate of investment of U. S. dollars in foreign chemical plants. As one well-informed Washington chemical engineer puts it, "The deterrent to the building of chemical plants in foreign countries is only the lack of sound projects, not a lack of available funds."

—J. L. GILLMAN, JR.

For more information, turn to Data Service card, circle No. 12



## letters to the editor

### Technical chairman comments

To the Editor:

Following development of the Washington meeting technical papers program, the secret files and correspondence of the committee were micro-filmed and then burned, in accordance with customary procedure. Through some quirk, one document escaped the holocaust. Because it provides a seldom-glimpsed view of one of the most sensitive and important aspects of A.I.Ch.E. affairs, it is hereby offered with the thought that it might be of general interest to CEP's readers.

DEWITT O. MYATT  
Science Communications, Inc.  
Washington, D. C.

Chairman, Technical Program  
Committee

As a labor-saving idea, it sounded fine. (We were told in school that a guy who could get something done without working very hard was an efficient engineer and would get promoted.) Well, we had to do so much talking it might have been easier if we'd just worked, but anyway here's what we did.

There's a big outfit in Washington (it has nearly 5 million employees and hires a lot of outside help too) that was rumored to do some chemical engineering work once in a while. We got the idea of going to Management to line up some technical papers. We'd let them do the work and we'd get the credit.

So we asked them if they did chemical engineering and they said yes they did.

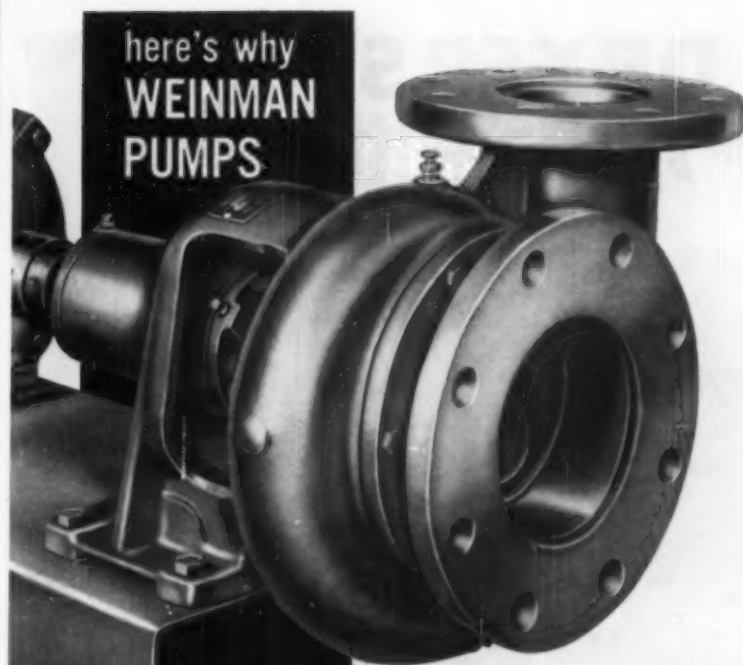
Then we pointed out that they had a reputation of being pretty close-mouthed and would they talk. And they said yes they would.

We wanted to be real sure, so we asked Management *very* politely if they felt they could make a respectable institutional presentation to an audience that knew so little about them.

Even when you're extremely polite, that's a tricky question to ask Management.

Management said they had some very fine people on their staff who

*continued on page 28*



here's why  
**WEINMAN  
PUMPS**

are  
preferred  
for safe,  
swift  
handling of  
corrosive  
liquids...

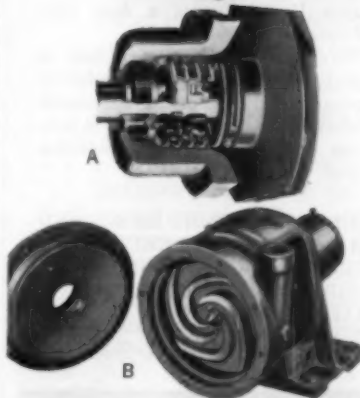
Chemical engineers rely on Weinman Types GB and KB Single Stage, End Suction Pumps as the standard for safe, positive pumping of all types of liquids. There's good reason for it, too. Designed to exceed industry specifications, Weinman's line of end suction pumps are available in full range of sizes to handle from 10 GPM to 2000 GPM. Rugged construction provides years of low maintenance service under the toughest conditions; heavy duty shafts prevent vibration and deflection; oversize bearings easily handle radial and thrust loads. And, corrosion-resistant metals protect all surfaces exposed to chemical action.

Many Weinman pump features were developed in collaboration with the chemical industry.

... for example, this special shaft seal (shown at left ... A) stops chemical leakage; reduces fire hazards; eliminates fumes and cuts waste.

... and this open type impeller (shown at left ... B) available for every size pump, speeds pumping of liquids with suspended foreign matter.

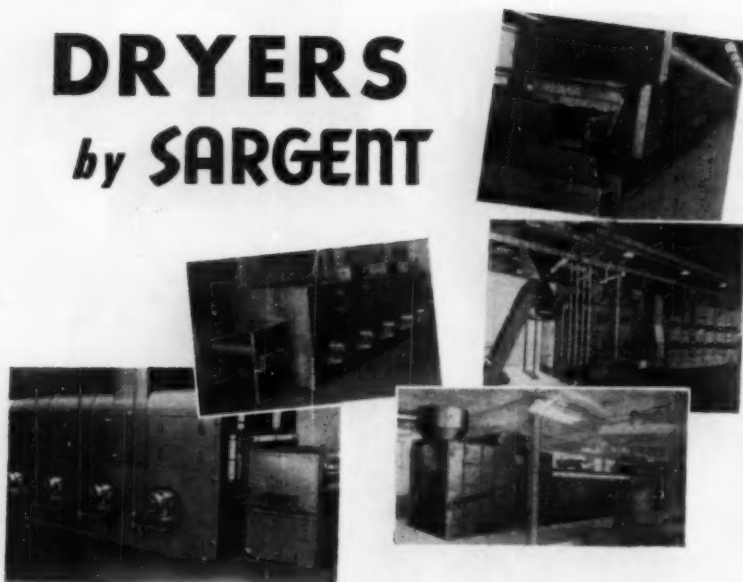
If you have a touchy chemical pumping problem...consult your Weinman Specialist. You'll find him in the Yellow Pages. Chances are he can recommend a standard pump that meets your precise need. If not, we'll work with you in solving your problem. Or write us direct for Bulletin 500.



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CENTRIFUGAL SPECIALISTS

For more information, turn to Data Service card, circle No. 75

# DRYERS by SARGENT



## The Most Sensible Way To Dry Solids and Semi-Solids

Single pass or multi-pass, single stage or multi-stage, a SARGENT perforated flight conveyor dryer will prove for you, as it has for many others throughout the chemical process industries, the best investment for continuous production of uniformly dried, top quality material at unprecedented economy.

With a SARGENT Dryer, dusting is reduced to a minimum . . . in many materials it is eliminated. There is little or no particle attrition. Material will not case harden. For semi-solids, a SARGENT Extruder with oscillating feed distributes over the conveyor an even, porous bed of material in pellet, rod or other form. Economy with a SARGENT starts with installation . . . SARGENT'S unique method of precision pre-assembly guarantees the fastest, easiest installation of

any dryer on the market. Labor and downtime for maintenance and cleanout are reduced to a minimum because of SARGENT'S exclusive design of quick and easy access to all sections. Every Sargent Dryer carries a firm performance guarantee.

We'd like to show you how a SARGENT can help you to better processing. Our modern research laboratory is fully equipped to help you with your drying problems. Just write us.

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POLE DRYERS • LAB DRYERS • COOLERS • FEEDERS,  
WEIGHING, VIBRATING SCREEN, OSCILLATING  
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For more information, turn to Data Service card, Circle No. 30

## letters to the editor

from page 27

were quite good at this sort of thing. They would delegate the job to them and we would see. The frost was an inch thick.

Everyone knows you don't go much further than that with Management.

Who do you think were the very fine people Management was talking about? They were only our good friends and neighbors and fellow chemical engineers. (Some of them, we discovered, were officially called materials engineers, or Colonels, or Directors, or chemists, or physicists, but they sure talked like chemical engineers. Anyone could see right off that their *work* was chemical engineering.)

Turned out we had an elephant by the tail after our friends got going. By the time we worked things out so you could see the beast from another angle or two we had to rent eight meeting rooms to get our program crowded into three days. (Well, that's *almost* true. We'd also talked to some folks who didn't work for that outfit—at least not full time—and they had a lot of stuff too good to let go too.)

But we sure got plenty of elephant.

Now, there's one trouble about an elephant. Even in three days, you can't really look it all over, real close up. And that's the kind of look we wanted. So while Management was busy with its important work we asked our friends to give us just the best pieces they could find. Maybe this was cheating a little bit, because we ended up with only a few slices. We got them from a lot of spots, but you still have to guess considerably to figure out what runs between them.

Well, that's the best we could do. But we had an awful thought while doing it. If the chemical engineering in that outfit is an elephant, what's chemical engineering itself and how do you get hold of that?

For full technical program details see page 114.

### What is time?

To the Editor:

It would be interesting to learn how Mr. Dean's Certificate of Membership (CEP, May, 1960, p. 155) which is dated October 20, 1908, bears a seal stating that the A.I.Ch.E. was incorporated in 1910.

M. L. ASROFF

Philadelphia

Reader Asroff gets this year's eagle eye award His query caused a bit of

*scurrying and digging into musty files. The following comment was unearthed from the report of the Membership Committee, A. C. Langmuir, Chm., dated December 10, 1910: "The Membership Committee has also worked on the certificate of membership to be issued to all members, and after great care has finally adopted a form which is at present in the hands of the engraver, and inside of a few weeks the printed certificates will be ready . . . This matter cannot be hurried because it is desired to have the incorporation brought about first and have the seal prepared with the incorporation statement on it. Otherwise this certificate would have been ready a little earlier." There is no mention of the date of the certificates, but we feel it probably seemed logical to the committee to show the date of entrance of the individual, rather than the date the certificate was issued.*

—Ed.

### Bouquet for Washington Scope

To the Editor:

My attention has been called to your Washington Scope article which was published in the June issue of CEP.

For myself, and for all the members of the staff here in the Office of Saline Water, I want to express our thanks for the kind words contained in the article concerning our endeavors.

A. L. MILLER, M.C.

Director  
Office of Saline Water  
Dept. of Interior

To the Editor:

Guess I'll have to subscribe to CEP to insure that I see the Washington Scope column regularly.

I wasn't much interested by the story on GATT, although Joe Gillman will be the first to tell me that I should be. The other columns were extremely interesting and, coming from a master, exceedingly well written. The only thing I can find to criticize is the presence of two or three 40-word sentences, but even these were lucid.

ARTHUR G. NORRIS

Branch Mgr.  
Vitro Engineering Co.  
Washington, D.C.

*Both readers refer to our Washington Scope feature which appears in the first section of CEP each month, and which is a welcome addition well done by Joe Gillman—Ed.*

## HOW MANY OF THESE Lapp "SPECIAL SHAPE" PORCELAINS CAN YOU IDENTIFY?



Probably not too many. That's because these are all custom-made porcelains, produced for specialized needs.

Lapp Chemical Porcelain in customized shapes has solved thousands of problems where acid and/or abrasion-resistant surfaces are required.

Other important considerations are the low cost of raw materials (especially when compared with high alloys), the advantageous physical properties of Lapp porcelain (hardness, density, zero absorption, uniformity).

Custom-made porcelain can solve your problem and save you money. Ask us. Special shapes get special attention here at Lapp.

**WRITE** for description and specifications of Lapp Chemical Porcelain. Lapp Insulator Co. Inc., Process Equipment Division, 2010 Poplar Street, LeRoy, New York.

# Lapp

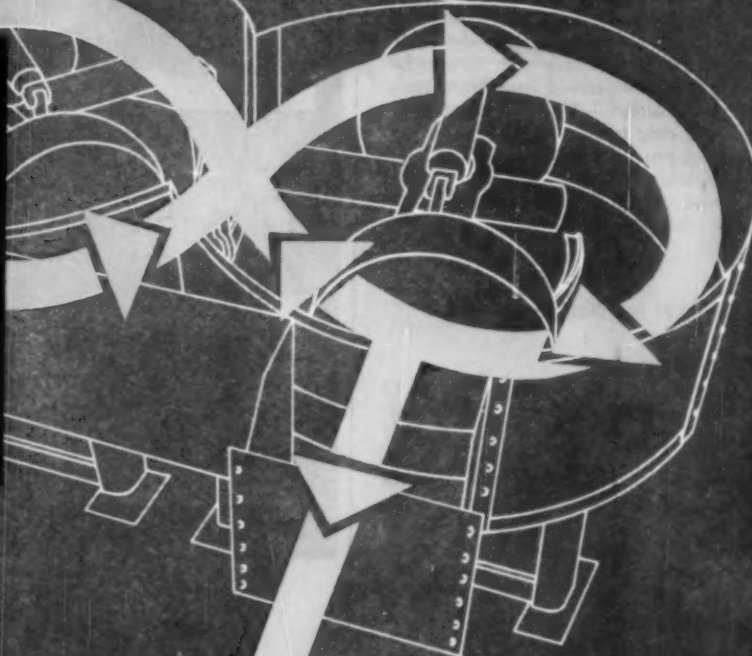
**ANSWERS:** 1. Steam ejector entraining chamber; 2. Paper maker's felt conditioner plate; 3. Cyclone Classifier; 4. Godet wheel for rayon filaments; 5. Funnel cock for etching machine; 6. Roll for rayon processing; 7. Condenser chamber; 8. Outlet liner for brick line tower.

For more information, turn to Data Service card, circle No. 69

**MIX-MULLER®** introduces a new era in mixing

## SIMPSON MULTI-MULL

a new concept in  
solids blending



### Controlled Dispersion breaks production barriers

The era of continuous mulling is here, now. The new Simpson *Multi-Mull* is specifically designed to deliver the quality of prepared material, which can be achieved only through mulling . . . in continuous high production quantities.

This means that many processors can take advantage of the benefits of controlled dispersion for the first time. It also means that many muller users can look forward to greatly increased mixing capacity and the elimination of many labor

and equipment problems involved with batch-type operations.

No cure-all, *Multi-Mull* is being introduced to do *certain* mixing jobs better and faster than they have ever been done before . . . under a performance guarantee\*. A full line of models ranging in pan retention capacities of from 6 to over 120 cu. ft. is available.

A new bulletin describes *Multi-Mull*. Write for your copy.



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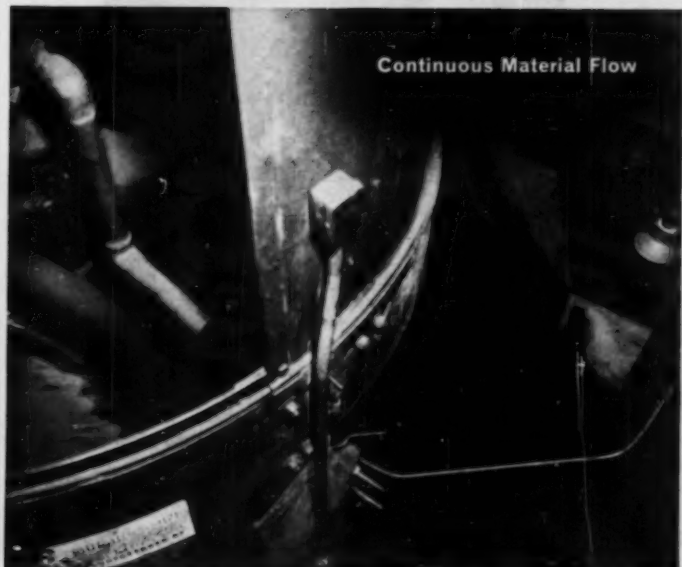
Six Models Available



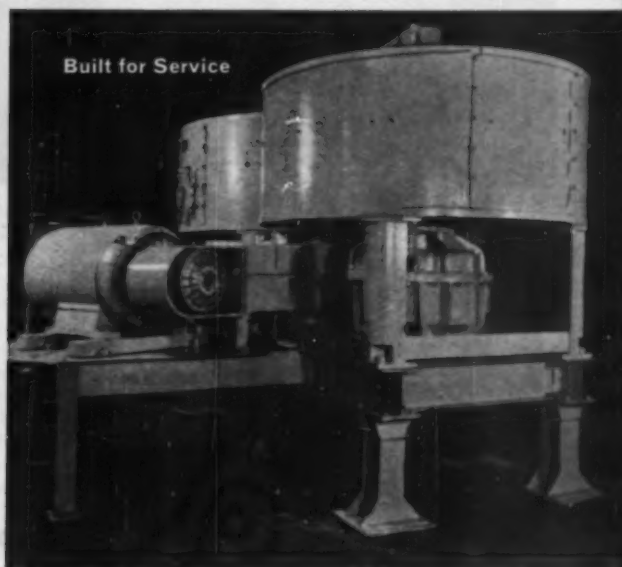
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## Advantages: Continuous Controlled Dispersion:

- No need for batch accumulating or storage components
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\*Multi-Mull Performance Guarantee . . . we will test the mulling characteristics of your material in a pilot unit. When you are satisfied with the quality of prepared material, we will specify equipment to match your production requirements. National Engineering Company will then build it, install it and not leave your plant until Multi-Mull satisfies the terms of the mutual agreement.



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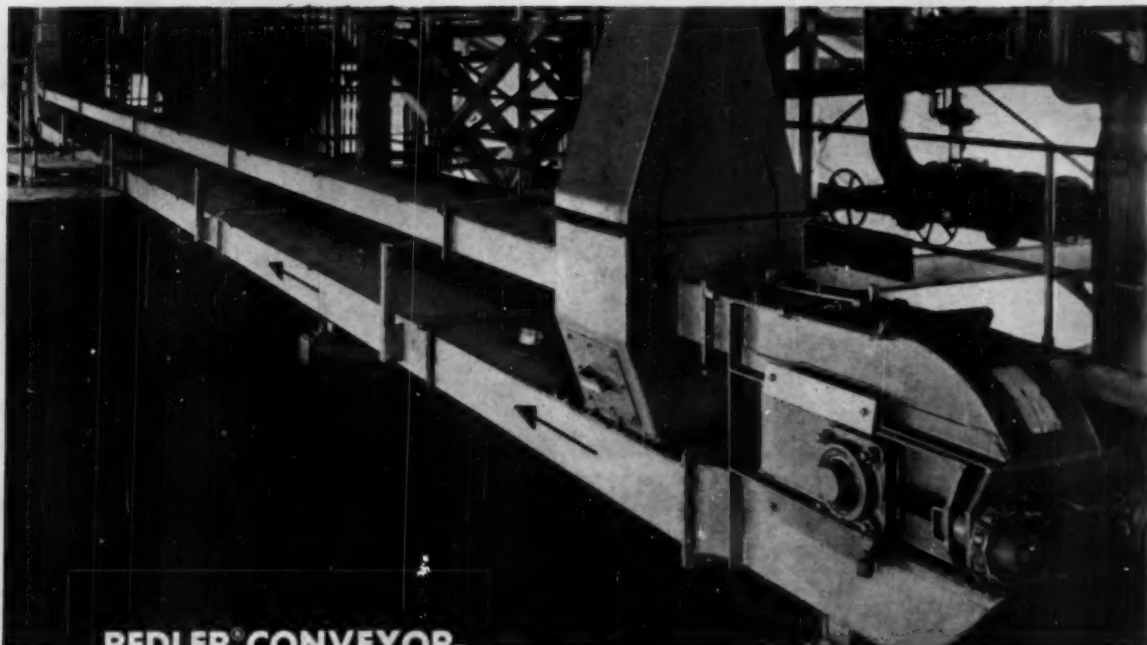
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ELEVATORS SPEED  
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HANDLING COST**

S-A REDLER Conveyor-Elevators have been in successful operation for over 25 years, with well over 20,000 units now handling a wide range of pulverized, granular, small lump and flaked materials, in plants throughout the world. The REDLER Conveyor-Elevator moves material by an EN MASSE action horizontally, vertically, on inclines, or around bend corners. All movement is continuous and takes place within totally enclosed, dust-tight, compact casings, permitting large tonnages to be handled in small space. The conveying element is a series of U-type skeleton flights which move readily around sprockets and bend corners with relatively low power required at the drive. Skeleton flights may easily be unhooked and replaced without tools. Handles up to hundreds of tons per hour and provides maximum versatility to handle hundreds of bulk chemical materials.

## S-A ENGINEERED PRODUCTS FOR CHEMICAL HANDLING SYSTEMS



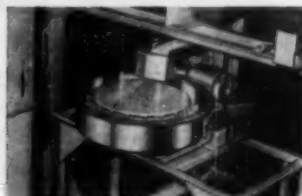
Cutaway Section REDLER Conveyor-Elevator shows skeleton flights loaded and unloaded.



"ZIPPER" CLOSED-BELT CONVEYOR-ELEVATOR—BULLETIN 349



BELT CONVEYORS—REQUEST CATALOG DATA



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OCTOBER 1960

## trends

### Canada's role in international picture

WILL FOREIGN EXPANSION of the chemical industry eventually freeze U. S. products from the world marketplace? This question has been answered by many people and many companies in many different ways. Most are vitally concerned over the increased foreign competition, and a major reaction has been the rapid entry of American companies into foreign operations both directly and through affiliates. This rapid growth has prevented any real stabilization of conditions, hence it is difficult to make a positive overall appraisal. Each analysis is rapidly outdated as the new plants come onstream to bolster production and capacity figures.

#### Canadian comparison

The difficulty in trying to foresee developments in the over-all international picture makes recent statistics on Canada especially worthwhile reading. Canada is a country which has experienced a sharp growth in its chemical industry. It has always relied heavily on imports from the U. S. Therefore it can almost be regarded as a "test market" in the international scheme. What has happened in Canada is interesting.

The statistical picture has been developed largely from the Canadian government's Dominion Bureau of Statistics and neatly packaged by a Canadian publication, *Chemistry in Canada*. In the 10-year span, 1949-59, the physical volume of production of Chemical and Allied Products has doubled. This took place while All Industrial Production increased from an index of 100 in 1949 to 165.4. Value of factory shipments of Chemical and Allied Products in 1959 came to \$1.38 billion. Biggest output was in Heavy Chemicals, \$300 million. Other high output categories were Medicinals and Pharmaceuti-

cals, \$165 million; Paints and Varnishes, \$147 million; Soaps and Washing Compounds, \$137 million; Plastics (primary only), \$104 million; and Fertilizers, \$94 million. Production of most chemicals during the ten years has been on a generally rising curve.

#### Imports and exports

While the domestic output of Chemicals and Allied Products in Canada has been on the increase, so have imports into Canada. Imports increased from \$192 million in 1951, to \$327 million in 1959. During this period, the U. S. has been the prime beneficiary. In 1951, the U. S. accounted for about 86% of the total. It has accounted for roughly the same proportion during the years; in 1959 its share was 84.5%. As might be expected, there have been fluctuations in the individual chemical group's share of the imports into Canada. Caustic soda and soda ash have been on a downtrend; sodium bicarbonate and borax have been holding fairly steady; plastics and crude glycerine have been on an upswing.

Canadian exports hit a high in 1956 when \$228 million of Chemicals and Allied Products were sent out of the country. A decline set in the following year with a dip to \$195 million, and a modest recovery is now being made. In 1959 exports of chemicals came to \$202 million. The U. S. purchased 42% of Canada's exports.

No blanket extrapolation can be made from the Canadian chemical industry to the worldwide scene. However, the optimistic note which can be gained from Canada is the fact that as chemical consumption goes up, so does demand.

# DOES YOUR PROCESS SUFFER FROM B.O.?

\* BAD ODORS, DUST, VAPORS, ETC.

A Graham Fume Scrubber will remove it. The New Graham Fume Scrubbers are a modern concept of the water-operated vacuum jet. Here is what they can do for you —

1. REMOVE GAS, VAPORS AND DUST FROM ANY SPACE
2. PREVENT ATMOSPHERIC CONTAMINATION
3. RECOVER VALUABLE PRODUCTS
4. PROVIDE DRAFT ON COMBUSTION FURNACES
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## opinion and comment

### Spring cleaning in the Fall

A MESSAGE FROM CHILE BRINGS to mind the thought that some constructive spring cleaning is in order despite the time of year. Luciano Cabala P., Universidad De Concepcion, Santiago, Chile, has written outlining the rebuilding job faced by the Engineering School. The quake-ridden days of last Spring dealt the University a five million dollar loss. The chemical and mechanical engineering departments, which are the two specialties of the school, suffered damages to their buildings and library, and lost a large quantity of glass equipment, instruments, and work units in different laboratories. Students lost their books and work implements when dorms were destroyed. Activities on campus were suspended until this Fall, and the University is trying to get back on an operating basis.

Cabala, who is president of the Institute of Chemical Engineers in Chile, says there still exists a desperate need for equipment and materials. Individuals and industry are urged to send books, supplies, or equipment suitable for the Ch.E. and M.E. courses directly to our neighbors in Chile. It's our guess that this immediate request will be generously met.

#### Need at home

Chile's plight serves to focus attention on similar—though far less drastic—needs of other engineering schools. It is no novelty to find a school or department with a desire to expand its facilities hampered by a lack of funds. Rapid technological developments in the industrial world are not directly reflected in the engineering labs on cam-

puses. Many are still using equipment obtained a generation or more ago. A solution is near at hand which can be painless to industry, yet a real bonanza to the schools.

Practically every plant in the country has idle units or equipment on hand. There are, in point of fact, units which have less than five years service life behind them, but which have been idled by an exploding technology which has made them inefficient. Some of the units are mothballed for contingencies. Others are gradually cannibalized for spare parts. Some of this equipment is ideal for use in schools. Much of it is properly scaled to be suitable for pilot plant and laboratory uses. The A.I.Ch.E. has been aware of the situation, and has a Sub-Committee on Surplus Equipment set up to serve as a clearing house to match donated equipment to specific needs.

#### A simple solution

What can industry do? It's really quite simple. Don't limit your housecleaning to one specific time of the year. Make it a year-round effort. Run a constant check on your surplus equipment. If it's adaptable to school needs, the next step is simple. Drop a note to the Sub-Committee Chairman, Prof. Russ Heckman, South Dakota School of Mines and Technology, Rapid City, S. D. He'll tell you where to ship the materials. Or if you wish, just contact us at CEP. We'll see that the message gets to the right place. Or you can simply check your local campuses.

In any event, put that idle equipment to work turning out better engineers—How can you lose?

L. R.

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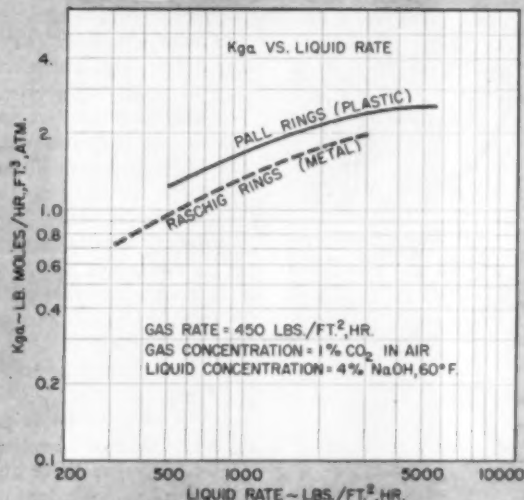
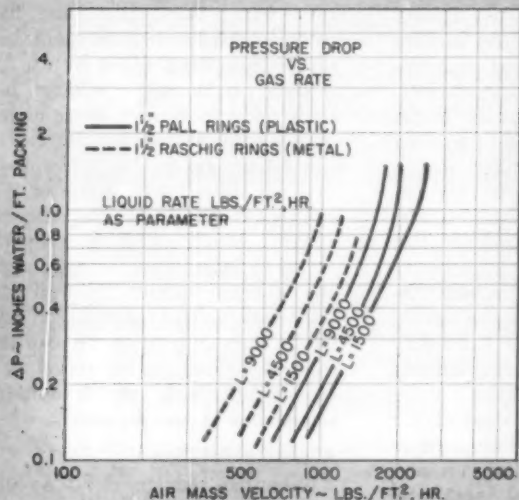
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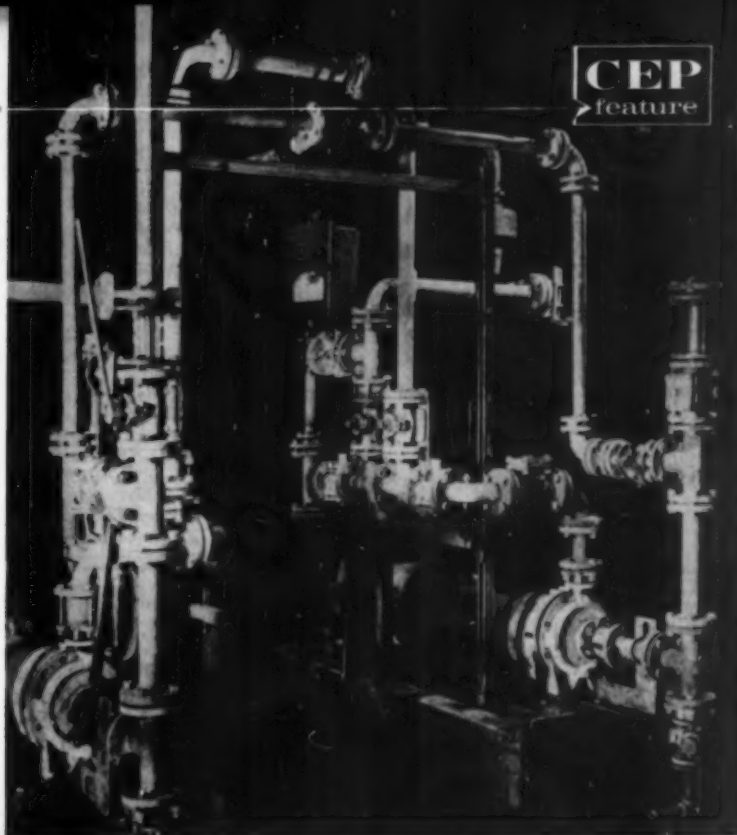
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ROBERT P. BRINGER  
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Resistoflex Corporation's Teflon TFE-fluorocarbon resin-lined pipe installed at DuPont's Niagara Falls plant where HCl and organic liquids are processed.

## Fluorocarbon polymers meet corrosion challenge

Fluorinated plastics, elastomers, oils, greases, and waxes provide unique thermal, mechanical, and corrosion resistant properties.

**F**LUOROCARBON POLYMERS, because of their general inertness and rarity, may be considered "noble" among polymeric materials as gold, silver, and platinum are considered "noble" metals. The presence of fluorine renders the compounds inert to almost every chemical. This inertness, coupled with heat resistance and a variety of other useful properties, makes the fluorocarbons rare indeed among polymers.

Ten years ago the types of fluorocarbons available were not only as rare but almost as costly as the "noble" metals. Today, largely because those interested in besting cor-

rosion have recognized the long term economics of quality protection, usage has increased and prices have tumbled. In addition, the polymeric types and forms have increased to the point where the fluorocarbon polymers can be applied in almost any corrosive situation demanding any unique combination of properties.

### Fluorinated polymer applications

The advantages of polymers as protection against corrosion are many. They can be applied as paints, lacquers, baked-type coatings, rubber and plastic linings. They may be used directly as mechanical parts, piping,

lubricants, or electrical insulation. Today's chemical processes (and hereina must be included missiles and rockets) are increasingly demanding in their use of extremely high and low temperatures and unusually corrosive chemicals. Most polymeric materials are sensitive to wide temperature variation and/or chemicals. Even those that are applicable in some extreme situations often lack the mechanical properties of common thermoplastics (flexibility, impact strength, etc.).

The fluorocarbon polymers provide an effective answer to both heat and chemical attack. They are being used

Table 1. Commercial fluorocarbon polymer glossary.

POLYMER	TRADE NAME	MANUFACTURER
<b>Plastics:</b>		
Poly-TFE	Teflon	DuPont
Poly-CTFE	Kel-F plastic	M.M.M.
Poly-(TFE-HFP)	FEP 100	DuPont
Poly-(CTFE-VF <sub>2</sub> )	Kel-F plastic	M.M.M.
Poly-VF <sub>2</sub>	RC-2525	Pennsalt Chemicals
Poly-VF	Teslar PVF film	DuPont
<b>Elastomers:</b>		
Poly-(CTFE-VF <sub>2</sub> )	Kel-F elastomer	M.M.M.
Poly-(VF <sub>2</sub> -HFP)	Fluorel elastomer	M.M.M.
	Viton	DuPont
<b>Oils, greases, and waxes:</b>		
Poly-CTFE	Kel-F oils, greases, and waxes	M.M.M.
	Fluorolube	Hooker Chemical
	Halocarbon	Fluoro-Chem Corp.

at temperatures as low as  $-425^{\circ}\text{F}$  and as high as  $550^{\circ}\text{F}$ , a remarkable  $975^{\circ}\text{F}$  range. Add to this mechanical properties which are comparable to other polymers, outstanding electrical insulation properties, extremely low coefficients of friction, zero moisture absorption, unusual optical properties, and unlimited fabrication possibilities. The result is a family of polymers which comes closer to the ideal than any other polymer available today.

Practically the entire commercial fluorocarbon field is derived from five basic monomers (Table 1). They are tetrafluoroethylene (TFE), chlorotrifluoroethylene (CTFE), vinylidene fluoride (VF<sub>2</sub>), hexafluoropropene (HFP), and vinyl fluoride (VF). Homopolymers of four of these monomers are now available. The fifth monomer, HFP, does not respond readily to homopolymerization (7). In

addition, several copolymers are on the market.

### Selecting polymer materials

When an engineer is confronted with a corrosive situation demanding the application of a fluorocarbon polymer, he has a choice available. The particular application will, of course, dictate the form of polymer necessary. In most cases a plastic will fill the bill. However, if extreme flexibility or application out of solution is required, an elastomer might be used. If the situation calls for an inert fluid or lubricant, then one of the lower molecular weight oils, greases, or waxes can be utilized.

The environmental situation may or may not limit the choice of fluorocarbon polymer. The environment is composed of two major factors in this case, temperature and chemical



Bringer



Sovia

Robert P. Bringer joined Minnesota Mining and Manufacturing in 1959, and is presently working on process development of fluorocarbon plastics and elastomers. Bringer has a B.S. and Ph.D., in chemical engineering, from Purdue U. He was formerly with Dow Chemical.

Cedric C. Sovia is in plastics technical service at 3M's Chemical Division. After ten years in basic tool and machine design, he concentrated on tooling for plastics and plastics parts design. Sovia formerly had his own business in job shop tool and parts design in the Minneapolis-St. Paul areas. He has several patents in plastics applications.

exposure. Another environmental factor might be radiation. The physical situation may also necessitate the use of a particular polymer. Tensile, impact, or compressive strengths; the elastic moduli; or abrasion resistance can often be as important as chemical or heat resistance.

Other properties not commonly thought of in conjunction with temperature and chemical resistance could be the decisive factors in the final choice of a fluorocarbon polymer. Examples might be electrical properties, infrared transmission, or thermal coefficient of expansion.

Another very real factor is fabrication. Can the polymer be fabricated into the desired shape? Although there are within the fluorocarbon family unlimited fabrication possibilities, fabrication techniques and abilities vary from polymer to polymer. Quite possibly the polymer which has the most desirable mechanical and chemical properties is the least desirable from a fabrication standpoint.

The important thing for the engineer to consider in choosing the proper fluorocarbon polymer is the correct combination of properties for his given application. With a general knowledge of the forms and chemical structure of available fluorocarbon polymers and their associated properties, the engineer can more profitably make this choice.

### Fluorocarbon plastics

The homopolymers of TFE and CTFE form the backbone of the fluorocarbon plastics industry. The other homopolymers and copolymers are either relatively new or have not at-

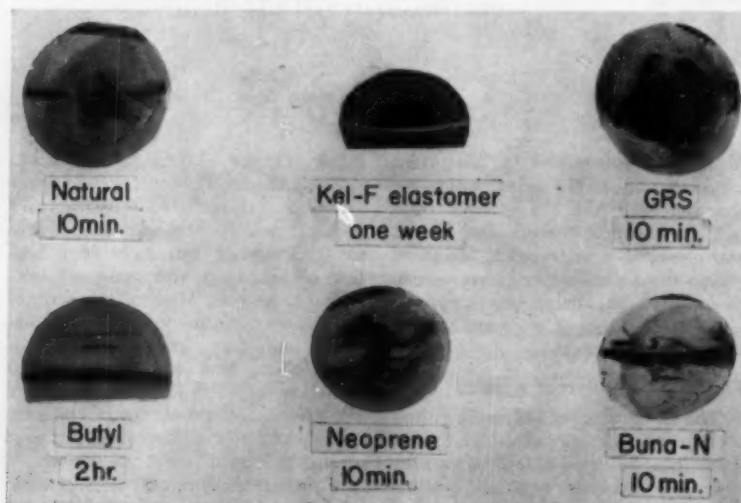
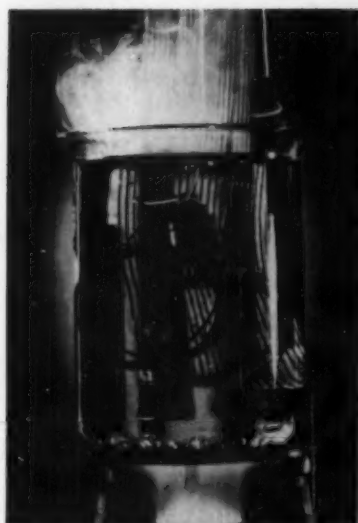


Figure 1. Strips of elastomers after immersion in red fuming nitric acid.





DuPont's new Teflon FEP-fluorocarbon resin and film being boiled in hot concentrated sulfuric acid.

tained the significant usage of poly-TFE and poly-CTFE. These plastics are available as virgin, plasticized, or reinforced powders and pellets; dispersions; primers; and glass cloth laminates.

Poly-TFE was introduced commercially in 1943. Due to its almost completely fluorinated structure, it is one of the most chemically inert polymers known. It is seriously affected only by chlorine trifluoride and fluorine at high temperatures and by molten alkali metals. It is recommended for continuous use up to 500°F.

Along with its excellent resistance to heat and chemicals, poly-TFE possesses certain undesirable properties, as do all materials of construction. These drawbacks have opened the way for the development of competing resins. These newer plastics have overcome many of the deficiencies of poly-TFE, but at the expense of heat and chemical stability.

The major deficiency of poly-TFE is in fabrication. It is a very high molecular weight polymer which cannot be fabricated in the same manner as true thermoplastics (i.e. extrusion, molding, etc.). Sintering techniques, such as those employed with powdered metals, must be used. The manufacture of complicated shapes is especially difficult and costly.

Poly-TFE also has poorer strength properties below 250°F than other fluorocarbon plastics. The polymer has a tendency to cold flow although the extent of this can be reduced by the use of fillers or confining spaces. Poly-TFE, however, because of its superior

Table 2. Effect of chemicals on poly-CTFE.

CHEMICALS	Seven day immersion—Wt. % change				
	25°C	70°C	90°C	135°C	175°C
Nitric acid, white fuming	0.0	..	0.3	..	..
Sulfuric acid, conc.	0.0	0.0	..	..	..
Chromic acid solution	0.0	..	..	..	0.0
Hydrofluoric acid, anhyd.	0.0	..	..	..	..
Aqua Regia	0.0	..	..	..	..
Sodium hydroxide, 30%	0.0	..	..	..	-1.2
Ammonium hydroxide, 28%	0.0	..	0.3	..	0.6
Bromine	0.0	..	..	..	..
Ethyl alcohol	0.0	..	..	0.4	..
Ethylene glycol	0.0	..	..	..	0.0
Methyl ethyl ketone	0.2	..	4.6	4.9	..
Butyl acetate	0.3	..	5.8	6.5	..
Formaldehyde	0.0	..	..	0.7	..
Ethyl ether	3.8	..	..	..	..
n-Heptane	0.0	..	1.8	..	..
Benzene	0.2	..	7.0	107	..
Carbon tetrachloride	0.4	9.7	18	600	..
Titanium tetrachloride	..	..	2.6	..	..

Table 3. Properties of fluorocarbon plastic.

PROPERTY	POLY-TFE	POLY-CTFE (TFE-HFP)	POLY-CTFE (TFE-HFP)	POLY-CTFE (TFE-VF <sub>2</sub> )	POLY-VF <sub>2</sub>
Specific gravity	2.1-2.2	2.1	2.1-2.2	2.1	1.76
M. P., crystalline, °F	620	419	545	383	340
Max. recommended service temp., °F	500	390	>400	390	300
Tensile strength, 1000 lb./sq. in.	1.5-3.0	4.6-5.7	3.0	4.5	7.0
Elongation, %	270-360	125-175	370	150-180	300
Modulus of elasticity, 1000 lb./sq. in.					
in tension	38-65	192-226	..	..	120
in flexure	78	182	82	167	200
in compression	80	177-191	..	115	120
Compressive strength, 1000 lb./sq. in.	1-10	27-80	..	..	10
Impact strength, Izod notched (ft.-lb./in. on notch)	2.5-4.0	3.6-4.0	..	No break	3
Hardness, Durometer, D scale	65	80	55	73	80
Abrasion resistance, mg./1000 cycles	..	8	13	..	35
Thermal Coeff. of Linear Expans., °F <sup>-1</sup>	5.5x10 <sup>-4</sup>	4.5x10 <sup>-4</sup>	..	4.3x10 <sup>-4</sup>	8.5x10 <sup>-4</sup>
Heat distortion temp., °F					
at 66 lb./sq. in.	250	196-201	162	..	300
at 264 lb./sq. in.	..	151-178	129	..	195
Brittleness temp., °F	-148	-121	-130	..	-80
Radiation resistance, megareps	..	>24	..	>24	>100

chemical and heat stability, is today the most widely used fluorocarbon polymer.

Poly-CTFE is a true thermoplastic which can be fabricated by conventional extrusion and molding techniques at high temperatures (500-625°F). The introduction of chlorine breaks up the completely fluorinated structure found in poly-TFE, thereby improving processibility with only relatively small losses in heat and

chemical stability. The bond energies of the carbon-fluorine and carbon-chlorine bonds partially explains this reduction (1). Table 2 points up the effect of chlorine inclusion on chemical stability. As can be seen, the corrosive acids and bases have no effect on poly-CTFE. Some highly halogenated and aromatic solvents tend to swell the polymer at higher temperatures but do not attack it chemically. Poly-CTFE is tougher and stronger

and has less tendency to cold flow than poly-TFE. Table 3 compares the physical properties of the fluorocarbon plastics.

Poly-(TFE-HFP) is a copolymer which retains the chemical stability of poly-TFE but can be fabricated by more conventional techniques (625-750°F). Due to its branched structure it is not as heat stable as straight chain poly-TFE. Its mechanical properties are essentially the same as poly-TFE (2).

Poly-(CTFE-VF<sub>2</sub>) is a copolymer which has certain advantages over poly-CTFE. It is easier to fabricate, has higher impact strength, and longer flex life. The introduction of hydrogen, however, lowers the chemical stability and strength of the poly-CTFE chain.

Poly-VF<sub>2</sub>\* has just recently been introduced. The inclusion of considerable hydrogen into the poly-TFE chain reduces the chemical and thermal stability of this polymer much below that of poly-CTFE. Poly-VF<sub>2</sub> has good mechanical strength, radiation resistance, and can be fabricated by conventional means (3).

Poly-VF has been introduced as a film product which has good strength, high temperature resistance, excellent flex life, low shrinkage, but only fair chemical resistance when compared with other fluorocarbon plastics (4).

### Elastomers in infancy

The fluorocarbon elastomer field is still in its infancy. The need for flexible polymers which are highly resistant to heat and chemical attack

\* Assumed structure

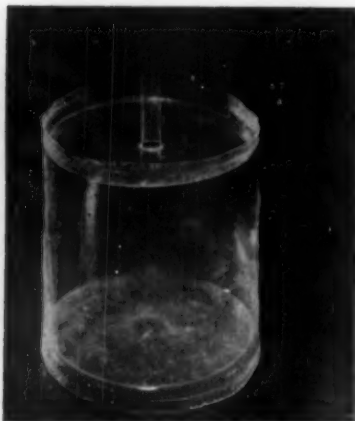


Figure 3. Poly-CTFE expellent bladder employed as a liner in missile fuel chambers for storing corrosive oxidizers as liquid oxygen, fuming nitric acid, and 90% hydrogen peroxide.

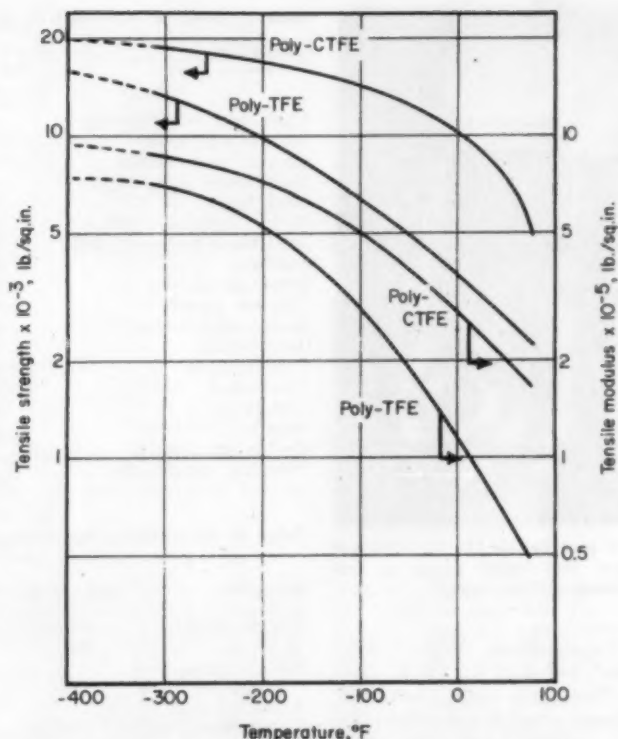


Figure 2. Low temperature tensile properties of typical fluorocarbons.

is obvious. The available types of elastomers are limited, probably due to the fact that the chemical industry has not yet realized their full utility.

Poly-(CTFE-VF<sub>2</sub>) elastomers are copolymers which were the first entrants of fluorocarbons into the elastomer field. At the time of their commercial introduction in 1955, they represented a great improvement in maximum heat and chemical resistance available in rubbers, Figure 1. The two available types of poly-(CTFE-VF<sub>2</sub>) elastomers (Kel-F elastomers 3700 and 5500) differ in copolymer composition, but have practically the same physical and chemical properties. The 3700 elastomer does show some superiority in tensile strength, low temperature flex, and resistance to hydrocarbon fuels (5).

Poly-(VF<sub>2</sub>-HFP) is the most recent entry into the fluorocarbon elastomer market. It features several improvements over the poly-(CTFE-VF<sub>2</sub>) elastomers. Table 4 compares typical properties of the three compounded elastomeric polymers. Poly-(VF<sub>2</sub>-HFP) is superior after exposure at high temperatures in air, hydrocarbon fuels, motor oil, and diester oil. It has at least a 150°F advantage in thermal stability. It is also the most easily processed of the fluoro-

carbon elastomers. In fact, the major difference between the two poly-(VF<sub>2</sub>-HFP) elastomers commercially available (Fluorel and Viton) is in processing characteristics. Poly-(VF<sub>2</sub>-HFP) is somewhat inferior to poly-(CTFE-VF<sub>2</sub>) in acid resistance and electrical properties.

### Oils, greases, and waxes

Poly-CTFE in very low molecular weight form is available as oil, grease, or wax. These materials retain the heat and chemical resistance

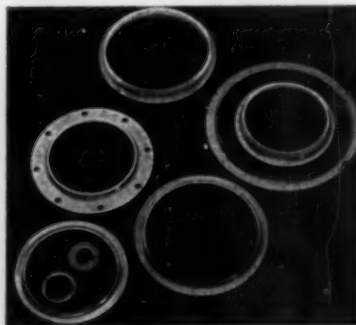


Figure 4. Poly-CTFE is used as lip seals for rocket fueling systems employing LOX because of its excellent low temperature properties, thermal shock resistance, and chemical inertness.



of the two retains the frictional characteristics of poly-TFE and the low cold flow characteristics of poly-CTFE, while attaining a wear resistance superior to either of the individual polymers.

The electrical properties of the fluorocarbon polymers make them useful as insulations in the presence of chemicals and/or at high temperatures (Table 7). The dissipation factor associated with poly-TFE is among the lowest known. A corollary property is zero moisture absorption, which is very important in electrical applications. The presence of water or high humidity can mean a reduction of insulating properties if the insulating material absorbs water. Fluorocarbons do not absorb water nor do they allow water vapor or liquid to pass through. The chemical resistance of fluorocarbons is important in electrical components when they are used under ozone producing conditions. Typical applications include wire coating, cable jacketing, coil forms, electrical parts insulation, and printed circuitry.

The fluorocarbons have excellent weatherability, i.e., resistance to the elements and ultraviolet radiation. Poly-VF film, the least fluorinated polymer discussed, has been exposed outdoors for over seven years with only a 10% decrease in film elongation (4). Test results on poly-(TFE-HFP) suggest a 5-20 year period of outdoor weathering without change in physical properties (2).

The liquid and vapor permeability of fluorocarbon films is extremely low. The M.V.T.\* of poly-CTFE film (3 mil) is 0.00. Some typical chemicals which show zero weight loss after storage for over a year in 5 mil poly-CTFE bags are: ethanol, 38% HCl, 98% H<sub>2</sub>SO<sub>4</sub>, 70% HNO<sub>3</sub>, 37% formaldehyde, bromine, 50% NaOH, glacial acetic acid, n-heptane, and

\* Moisture Vapor Transmission, g./100 sq. in./24 hr. at 100°F. and 95% relative humidity.

**Table 5.** Bearing characteristics of fluorocarbons.

	COEFFICIENT OF FRICTION*	WEAR RATE** mg./hr.
Poly-CTFE	0.44	0.13
Poly-CTFE plus 56% poly-TFE, fused at 500°F	0.22	0.00
Poly-TFE	0.20	0.20

\* Plastic acting as bearing for a hardened stainless steel shaft, 1/2-in. diam., revolving at 300 rev./min. under 2200 g. load at 25°C.

\*\* Plastic acting as bearing for a Type 303 stainless steel shaft, 1/2-in. diam., revolving at 150 rev./min. under 2000 g. load at 25°C.

10% NH<sub>4</sub>OH. The permeability of poly-(TFE-HFP) to 98% H<sub>2</sub>SO<sub>4</sub> at room temperature is practically negligible ( $1 \times 10^{-6}$  gm./100 sq. in./24 hr./mil) (2).

The optical properties of some of the fluorocarbon polymers can also be utilized (Figure 5). The infrared transmission ability (90% at 3 microns wave length) of poly-CTFE, for example, in combination with heat resistance and strength has been useful for housing infrared sensing elements.

### Coating applications

The fabrication techniques necessary to form objects from fluorocarbon plastics have already been briefly discussed. However, of major interest in corrosion protection is the applicability of polymer coatings on process equipment such as reactors, tanks, piping, and pumps (Figure 6). Dispersions of both poly-TFE (in water) and poly-CTFE (in organic media) are available. They can be applied by most commercial methods but must be fused at relatively high temperatures (500°F for poly-CTFE and 700°F for poly-TFE) to form continuous protective films. The high fusion temperatures necessarily limit the types of materials which can be coated to metals, glass and glass fabrics, and ceramics.

The physical properties of the plas-

tic coatings are essentially the same as stated for the basic resins. The porosity of thin poly-TFE coatings is somewhat of a problem, especially in the presence of mineral acids. Poly-CTFE is less porous and in coatings greater than 4 mils has the same chemical stability as the base resin (6).

Almost any size container can be coated depending on the oven facilities available. Tank cars and trucks have been coated.

Both poly-TFE and poly-CTFE glass laminates are available. These provide a continuous polymer surface on one side for chemical protection. The opposite side has a glass cloth structure which can be bonded to a substrate with a suitable adhesive. The use of glass cloth laminates essentially lowers the baking temperature necessary to that for adhesive cure. Consequently, less temperature resistant substrata can be utilized.

The fluorocarbon elastomers can also be used in coating applications. Although their chemical stability is not as good as the plastics, they have the advantage of being soluble in selected solvents (ketones, for example). Thin elastomeric films can thus be readily applied from solution. Lining with elastomer sheet can also be accomplished by the use of adhesives. The flexibility of the elastomers aids considerably in conforming to the shapes of surfaces to be lined. Of less interest are the temporary air dried coatings which can be obtained with the low molecular weight poly-CTFE waxes and greases.

### Summary

The fluorocarbon polymers today are a family of materials which exhibit the heat and chemical resistance associated with fluorine. With the many types available, the engineer can be selective in demanding the proper combination of properties for a given application. As usage continues to increase, prices can be expected to continue to decrease. Also, with more companies carrying on fluorocarbon research than ever before, the advent of still better polymers onto the corrosion scene is inevitable.

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**Table 7.** Typical electrical properties.

PROPERTY	POLY-TFE	POLY-CTFE	POLY-(TFE-HFP)	POLY-(CTFE-VF <sub>2</sub> )	POLY-VF <sub>2</sub>
Dielectric strength short time (1/2 in.), volts/mil	400	450	..	..	260
Volume resistivity ohm-cm.	10 <sup>19</sup>	10 <sup>18</sup>	2x10 <sup>15</sup>	10 <sup>16</sup>	2x10 <sup>14</sup>
Dielectric constant					
60 cycles	2.0	2.65	..	..	8.4
1000 cycles	2.0	2.54	2.2	..	8.0
10 <sup>6</sup> cycles	2.0	2.34	..	2.27	6.6
Dissipation factor					
60 cycles	0.0002	0.015	..	..	0.049
1000 cycles	0.0002	0.018	0.0002	..	0.018
10 <sup>6</sup> cycles	0.0002	0.005	..	0.0082	0.17





GEORGE P. GLADIS  
The International Nickel Co.

## Effects of moisture on corrosion in petrochemical environments

Warning—small amounts of water, although often overlooked, can transform relatively innocuous dry halogenated chemicals into aggressive corrosives, causing considerable equipment deterioration and product contamination. Corrosion test data for common materials of construction are available. In addition, practical tips for extending the service life of process equipment are given.

THE EXPANDING PETROCHEMICAL INDUSTRY continues to develop new processes and products at a rapid pace, but not without creating additional problems in selecting suitable materials of construction for process equipment. Any attempt to cover the corrosion problems arising in this extremely wide and diversified field in a single presentation would result in a very sketchy outline at the best. Accordingly, the subject material in this article will be limited to the examination of one particular source of corrosion found in many petrochem-

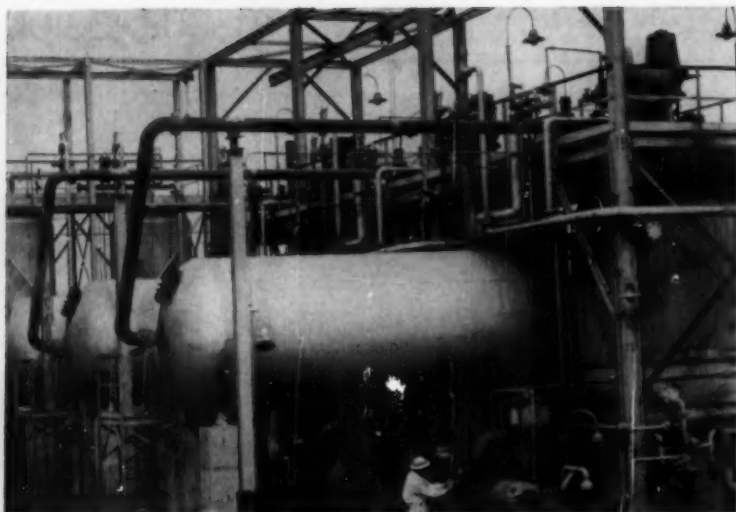
ical operations and often overlooked as a cause of considerable equipment deterioration and product contamination. This singular cause of corrosion is the detrimental effect of moisture or water in some chemical environments.

Many types of chemical reactants, intermediates, or products are relatively innocuous when dry (moisture-free). However, in the presence of water, some of these normally harmless compounds may reveal a considerably more aggressive nature. Recognition of this behavior can lead to a

lessening of corrosive attack, where these materials are handled, by careful control of process conditions or by selection of appropriately resistant materials of construction.

### Chlorinated hydrocarbons

Large tonnages of chlorinated hydrocarbons (chlorohydrocarbons) are produced from natural gas, petroleum gases, and their components for use as starting materials and intermediates for further petrochemical processing steps or as finished products. As intermediates, the chlorinated hydro-



Piping, pumps, and valves for handling corrosive aluminum and hydrogen chloride catalysts at Phillips Petroleum's Borger, Texas, installation are made of Hastelloy alloy B. (Photo courtesy of Haynes Stellite Company).

carbons are utilized for production of plastics, resins, rubbers, plasticizers, detergents, solvents, synthetic fibers, automotive chemicals, and agricultural chemicals. They are particularly useful in finished form as refrigerants and as solvents for metal degreasing, dry cleaning, and oil and fat extraction.

Chlorinated compounds normally are not corrosive to most metals and alloys when free from water and at ordinary temperatures. However, in the presence of water and especially at higher temperatures, difficulties may arise because of the tendency of these compounds to hydrolyze and to form acidic decomposition products. Chlorohydrocarbons may also decompose by oxidation and pyrolysis. Pyrolysis generally occurs at elevated temperatures (above 750°-1000°F). Oxidation also occurs more readily at high temperatures and in the presence of light and catalyzing impurities. Inhibitors can be used to minimize decomposition by oxidation, but there is some question whether inhibitors can prevent hydrolysis *per se*.

An appreciable degree of breakdown of chlorinated organics to form HCl by hydrolysis usually is favored when certain conditions are met:

1. There must be sufficient water present. This reaction is slow when all the water present is dissolved in the chlorinated organic and is more rapid when free or excess water is present. However, it can be noted from Table 1 (1, 2) that the solubility of water in chlorohydrocarbons is generally very low and small amounts readily lead to a condition of free or excess supply.

2. Hydrolysis usually proceeds more rapidly as temperatures approach the boiling point of the chemical. Boiling points for a number of chlorohydrocarbons are given in Table 1.

3. Metals such as iron, zinc, aluminum and their salts, for example, act as catalysts and tend to accelerate the decomposition of chlorohydrocarbons in the presence of water. Brallier (3) and more recently Calkins and Hawley (4) demonstrated that the rate of decomposition of  $\text{CCl}_4$  by hydrolysis is comparatively slow unless iron is present as a result of corrosion to provide a catalytic impetus. A number of investigators (5, 6, 7) have studied the behavior of aluminum in chlorohydrocarbons. The results of this work will be mentioned later.

Most of the chlorinated hydrocarbons are susceptible to hydrolysis to some degree. Methylene chloride,

methyl chloride, ethylene dichloride, carbon tetrachloride, and tri-, tetra-, and pentachloroethane are among those that readily hydrolyze. Others, such as tri- and perchloroethylene, chlorobenzenes, and benzene hexachloride are more stable and show a lesser tendency to hydrolyze. However, the latter compounds are not completely immune to hydrolysis. Long contact periods of exposure to catalytic type metals at higher temperatures in the presence of water will produce some decomposition of the more stable compounds.

### Corrosion by chlorohydrocarbons

The performance of a metal in a wetted and hydrolyzed chlorohydrocarbon will depend upon its inherent resistance to the corrosive action of HCl under the specific conditions encountered in the process. The factors usually affecting the behavior of a corrosive medium such as concentration, temperature, degree of aeration, velocity of flow, turbulence, stresses, and presence of contaminants that may act as accelerators or inhibitors of corrosion will influence the effect of the HCl on the life of the metal.

The effect of the metal in accelerating decomposition of the chlorohydrocarbon is a significant factor in its performance. However, the metals that act as catalysts have poor resistance to HCl and hence their use should be avoided on both counts.

The corrosiveness of a chlorohydrocarbon process environment is often intensified by the presence of small amounts of other compounds that are more aggressive when wet. For example, in chlorinating phenol to form dichlorophenol, an intermediate used in manufacturing the weed-killer 2,4-D (dichlorophenoxyacetic acid), small amounts of hydrogen chloride are formed and together with un-

Table 1. Boiling points and solubilities of some chlorohydrocarbons.

CHLOROHYDROCARBON	BOILING POINT (°F)	WEIGHT % SOLUBLE IN WATER (77°F)	WEIGHT % SOLUBILITY OF WATER IN CHLORO- HYDROCARBON (77°F)
Allyl chloride	113	0.36 (68°F)	0.08 (68°F)
Carbon tetrachloride	170	0.08	0.013
Chloroform	142	0.8	0.10
Ethylene dichloride	183	0.87 (68°F)	0.16 (68°F)
Ethyl chloride	54	0.51 (68°F)	0.14 (68°F)
Methylene chloride	104	1.32	0.20
Methyl chloride	-11	0.74 (86°F)	0.29
Pentachlorethane	321	0.05	0.03
Perchloroethylene	250	0.015	0.011
Propylene chloride	205	0.26	0.06
Tetrachlorethane (1, 1, 2, 2-)	295	0.29	1.13
Trichloroethane (1, 1, 2-)	237	0.45 (68°F)	0.05 (68°F)
Trichloroethylene	189	0.11	0.03

reacted  $\text{Cl}_2$  pose a corrosive threat through later process stages. The  $\text{Cl}_2$  and hydrogen chloride will react with any water in the system to form an additional content of corrosive  $\text{HClO}$  and  $\text{HCl}$ .

Carbon steel, cast iron, copper, brass, bronze, zinc and other ordinary metals can be used satisfactorily with most chlorinated hydrocarbons under dry conditions. However, it sometimes is difficult to prevent moisture pick-up in process lines and units. Moreover, steam is often introduced as an essential step in a process. The common metals can often be used adequately when free water is present with the more stable chlorohydrocarbons providing temperatures are well below the boiling point and contact time is short. The use of iron, steel, zinc, and aluminum may be more hazardous under these conditions because of their catalytic effect on hydrolysis. Corrosive attack of the common metals can be expected in the less stable chlorohydrocarbons when wet and particularly at higher temperatures.

## Corrosion test results

The following results of a number of corrosion tests, performed under process operating conditions and in the laboratory, demonstrate the behavior of metals and alloys in some wet chlorohydrocarbon media.

The behavior of carbon steel in a mixture of  $\text{H}_2\text{O}$  and various chlorohydrocarbons, both at room and boiling temperatures, is shown in Table 2. The marked increase in corrosion rates at the boiling point for all compounds verifies that hydrolysis has occurred to a greater extent in all cases at the higher temperature. The relative stability or resistance to hydrolysis of the compounds is indicated by the comparative rates of corrosion at the boiling points; trichloroethylene representing the most stable and  $\text{CCl}_4$  the least stable compound in the tested group.

In Table 3, carbon steel was the only metal showing a relatively active rate of attack in the wet  $\text{CCl}_4$  at room temperature. Monel\* nickel-copper alloy, "A" nickel, and lead were the only metals among those tested that maintained suitable resistance in wet  $\text{CCl}_4$  at the boiling point.

Because water tends to accumulate in the still or reboiler and in the bottom sections of distillation columns, the corrosive conditions are

\* Reg. Trade Mark, The International Nickel Company, Inc.

\*\* Reg. Trade Mark, Haynes Stellite Company.

**Table 2.** Corrosion of carbon steel in chlorinated hydrocarbons with water level present.

COMPOUND	CORROSION RATE (IN./YEAR)	
	86°F	B.P.
Carbon tetrachloride	0.008	0.16
Chloroform	0.002	0.002
Ethylene Dichloride	0.001	0.014
Trichloroethylene	0.001	0.007

likely to be more severe in those locations as compared with upper sections of a column handling chlorohydrocarbons. Temperatures are also higher in the vicinity of the reboiler. The difference in the corrosive conditions existing between the bottom and top locations in a  $\text{CCl}_4$  tower is well demonstrated in the case of the mild steel and cast iron specimens in Table 4. The austenitic stainless steels, Ni-Resist\* corrosion-resistant cast iron Type 1, and high nickel alloys maintained a good resistance in the reboiler despite the more severe conditions. As shown in Table 5 a pitting type of attack has occurred on Inconel\* nickel-chromium alloy and Type 304 and Type 316 stainless steel specimens during exposure in a trichloro-

ethylene still where corrosive conditions were intensified by the presence of water and steam.

Evidence of the severe corrosion conditions existing when  $\text{Cl}_2$  and hydrogen chloride are present along with water vapor in a chlorohydrocarbon medium at elevated temperature is affirmed in the test results given in Table 6. Hastelloy alloy C\*\* was the only material among those tested with any degree of resistance.

In Table 7 the fact that corrosion rates were higher than should normally be expected in a wet monochlorobenzene solution would indicate the probable carryover of trace amounts of hydrogen chloride reaction product.

## Corrosion in solvent systems

Chlorinated solvents are extensively used for extraction, refining, and in the processing of films, synthetic fibers, inks, lacquers, plastics and other finished petrochemical products. The recovery of the solvents is essential to keep process costs at a feasible level. A common method of recovering solvent vapors from air streams is by adsorption on activated carbon. In this system, air containing the solvent is passed through an adsorber

**Table 3.** Corrosion tests in carbon tetrachloride.

MATERIAL	CORROSION RATE, IN./YEAR			
	77°-86°F		BOILING POINT	
	WATER LAYER ABSENT	WATER LAYER PRESENT	WATER LAYER ABSENT	WATER LAYER PRESENT
Carbon steel	< 0.0001	0.008	0.0001	0.16
Aluminum	..	..	..	0.27
Yellow brass	< 0.0001	0.0006	0.0001	0.25
Lead	< 0.0001	0.001	0.0006	0.009
Zinc	..	..	..	0.044
Monel	0.0001	0.0001	< 0.0001	0.004
"A" Nickel	< 0.0001	< 0.0001	< 0.0001	0.002

**Table 4.** Corrosion tests in a continuous process for distillation and rectification of crude carbon tetrachloride.

**Test A**—Suspended in vapor stream above top plate of bubble cap rectification column.

$\text{CCl}_4$  (99.598%);  $\text{S}_2\text{Cl}_2$  (0.600%);  $\text{CS}_2$  (.002%)

Temperature: 170°F

Duration of test: 133 days

**Test B**—Suspended in column reboiler.

$\text{S}_2\text{Cl}_2$  (98.3%);  $\text{CCl}_4$  (0.13%);  $\text{FeCl}_3$  (0.01%)

Temperature: 280°F

Duration of test: 133 days

MATERIAL	CORROSION RATE, IN./YEAR		
	TEST A	TEST B	
		LIQUID	VAPOR
Carbon steel	0.008	0.22	0.22
Cast iron	0.007	0.13	0.16
Lead	Completely corroded	Completely corroded	
Ni-Resist cast iron Type 1	0.0005	0.002	0.001
Type 304 stainless steel	0.0002	0.0008	0.0004
Type 316 stainless steel	0.0002	0.0004	0.0004
Monel alloy	0.0003	0.0009	0.0003
"A" Nickel	0.0002	0.0003	0.0003
Inconel	0.0002	0.0006	0.0004



containing activated carbon supported on a perforated metal tray. The air flow is diverted to an alternate adsorber after the adsorption cycle is completed. The adsorbed solvent in the first unit is stripped from the carbon by low pressure steam. The solvent is reclaimed from the steam by condensing and decanting. The use of steam for stripping the solvent can create corrosion difficulties because the conditions tend to promote hydrolysis of the solvent.

The results of some corrosion studies in sections of a solvent recovery system where corrosion was a serious problem are given in Tables 8, 9, and 10.

The most severe corrosive attack occurred in the adsorbers, adsorber condensers, and decanter where carbon steel was readily attacked by hot dilute HCl conditions. Despite very low rates of general attack, the performance of the Types 304 and 316 stainless steel specimens was unsatisfactory because stress corrosion cracking had taken place on exposure in the adsorber and in the adsorber condenser entrance, locations where temperatures were of a higher order (212°-250°F). There was no evidence in the tests of stress corrosion cracking of the stainless steels in the condenser outlet, decanter, or other locations at which acid conditions presumably existed but where temperatures were lower.

These results confirmed some previous plant experiences with the stress corrosion cracking of stainless steel adsorber parts. Also, localized or pitting type of attack of metals in direct contact with the carbon particles is often accelerated by galvanic corrosion effects set up by the conductivity and nobility of carbon. The stainless steels are very sensitive to pitting in chloride-containing media. Monel nickel-copper alloy was selected for the adsorber components because of its resistance to attack by HCl and especially because of its invulnerability to stress corrosion cracking in hot acid chloride environments.

In activated carbon recovery systems operating at temperatures higher than those encountered in the aforementioned unit, it may be necessary to resort to metals higher in alloy content than Monel alloy. It is reported (8) that nickel-base and copper-base alloys were not sufficiently resistant in adsorbers in an installation utilizing steam at 300°-325°F for solvent stripping. Such alloys were replaced with Hastelloy alloy C which has since given highly satisfactory service.

**Table 5.** Corrosion tests in steam distillation and rectification of crude trichloroethylene.

Test A—Suspended in vapor above top plate where reflux enters column.  
Temperature: 158°F Duration of Test: 228 days  
Test B—Suspended in pot still. Alternately exposed trichloroethylene and water and trichloroethylene vapor and steam.  
Temperature: 212°F Duration of Test: 230 days

MATERIAL	CORROSION RATE, IN./YEAR	
	TEST A	TEST B
Copper	Completely corroded	Completely corroded
Red Brass	" "	" "
Lead	" "	" "
Type 304 stainless steel	< 0.0001	0.0007 a
Type 316 stainless steel	< 0.0001	0.0003 b
Inconel alloy	0.0001	0.0009 c
Monel alloy	0.0009	0.001
"A" Nickel	0.002	0.002
Hastelloy alloy B	0.0006	0.001
Hastelloy alloy C	< 0.0001	0.0001

a) 0.008 in. surface pitting, b) 0.004 in. surface pitting, c) 0.002 in. surface pitting

## Resistance of materials

Survey outlines performance of common metals and alloys found in systems handling wet chlorohydrocarbons, chlorine, ammonia, and sulfur dioxide.

This summary is confined to comments on the behavior of metals in contact with chlorohydrocarbons in the presence of water since most metals are resistant under anhydrous conditions.

**Steel and cast iron.** These metals are not recommended for use with wet chlorohydrocarbon media, particularly at hot temperatures.

**Copper and copper-base alloys.** Copper, aluminum bronze, red brass, silicon bronze, phosphor bronze, and cupronickels can be considered for use at atmospheric to warm temperatures but may be more rapidly attacked at temperatures near the boiling point. High zinc brasses are

susceptible to dezincification attack in hot HCl solutions.

**Austenitic stainless steels.** The resistance of the austenitic chromium-nickel stainless steels to general corrosion in wet chlorohydrocarbons is good. They have very little catalytic effect upon decomposition of the chlorohydrocarbons. However, despite a low rate of general corrosion, the austenitic stainless steels are susceptible to localized pitting-type attack in the presence of hot HCl. The vulnerability of the austenitic stainless steels to stress corrosion cracking in hot acidic chloride environments when under residual or applied stresses is another deterrent to their use in wet chlorohydrocarbons at hot temperatures.

**High nickel alloys.** The high nickel alloys have a negligible catalytic effect on the hydrolytic decomposition of chlorohydrocarbons. "A" nickel and Monel nickel-copper alloy have a very useful degree of resistance to hot dilute HCl and perform competently in applications involving hot wet chlorohydrocarbons. Hastelloy alloys B and C can be considered when the strength and temperature of the HCl is in a range too severe for "A" nickel or Monel alloy. Hastelloy alloy C is specially effective when



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**Table 6.** Corrosion tests in vapor containing 87.5%  $\text{CCl}_4$ , 12%  $\text{H}_2\text{O}$ , 0.4%  $\text{Cl}_2$ , and 0.1%  $\text{HCl}$ . Temperature was 185°F and test ran 65 hr.

MATERIAL	CORROSION RATE, IN./YEAR
Monel nickel-copper alloy	0.54 (perforated)
"A" nickel	0.13
Inconel nickel-chromium alloy	1.1 (perforated)
Type 304 stainless steel	1.6 (perforated)
Type 316 stainless steel	1.3 (perforated)
Hastelloy alloy B	0.89
Hastelloy alloy C	0.002

wet  $\text{Cl}_2$  or oxidizing agents are present.

**Aluminum.** The behavior of aluminum in chlorohydrocarbons is most unusual. Rhodes and Carty (5) found that aluminum was not attacked in dry  $\text{CCl}_4$  at room temperature and was corroded in wet  $\text{CCl}_4$  at a rate of 0.007 in./year. However, at the boiling point, aluminum was rapidly attacked in dry  $\text{CCl}_4$ . The corrosive attack was not as rapid and vigorous in the boiling  $\text{CCl}_4$ - $\text{H}_2\text{O}$  mixture but the rate was still high (0.16 in./year). In effect, the water acted as a temporary inhibitor at the boiling point by apparently helping to preserve the protective film.

Stern and Uhlig (6) demonstrated that the presence of water in boiling  $\text{CCl}_4$  delays the start of corrosion of aluminum temporarily but after the induction period (time of delay) the corrosion proceeds at a high rate. It was confirmed that the reaction of aluminum with chlorinated hydrocarbons is a direct chemical reaction resulting in formation of aluminum chloride and hexachloroethane.



Hamstead, *et al.* (7) reported the perforation failure of a type 3003 aluminum transfer line after a few hours exposure to refined propylene dichloride. Subsequent time-sequence laboratory tests in boiling propylene dichloride confirmed the susceptibility of aluminum to rapid attack in chlorohydrocarbons. The authors advise against using aluminum for equipment in contact with chloro-compounds until more work is done to define safe limits.

**Titanium.** Titanium shows satisfactory resistance when exposed to boiling water solutions of a number of chlorohydrocarbons (9). Titanium does not accelerate hydrolysis. However, titanium is unsatisfactory in reducing acids such as hot  $\text{HCl}$  and

would probably be seriously attacked in a hot wet chlorohydrocarbon environment containing  $\text{HCl}$ . But, if  $\text{Cl}_2$  is also present in the wet solution, the passivity of titanium is maintained and corrosion is stopped. There must usually be 50 or more p.p.m. of  $\text{H}_2\text{O}$  present with  $\text{Cl}_2$  to sustain passivity of titanium. Titanium failed in a perchloroethylene-carbon tetrachloride mixture saturated with hydrogen chloride and  $\text{Cl}_2$  at 250°F and containing 20-30 p.p.m.  $\text{H}_2\text{O}$ . This was not a sufficient amount of  $\text{H}_2\text{O}$  to provide passivity in the presence of  $\text{Cl}_2$  (10).

A new titanium alloy containing about 0.1% palladium has been developed by Union Carbide Metals Company. Laboratory tests have shown that the addition of the noble metal extends the service range of titanium by improving its performance in reducing environments such as dilute  $\text{HCl}$  without impairment of its high resistance to oxidizing media (11).

## Chlorine

Chlorine has truly become one of the chemical work-horses of petrochemical processing. Large tonnages of  $\text{Cl}_2$  are handled daily in the production of petrochemical intermediates and products.

Most metals and alloys are resistant to dry gaseous or liquid  $\text{Cl}_2$  at temperatures ranging from ambient to those at which high temperature corrosion occurs. However, in the presence of moisture and at temperatures below the dew point of the  $\text{Cl}_2$ - $\text{H}_2\text{O}$  mixture,  $\text{Cl}_2$  reacts to form  $\text{HClO}$  and  $\text{HCl}$  which are readily corrosive to most metals. Platinum, lead (230°F) (12), tantalum (300°F) (13), titanium, high silicon irons (room temperature), and Hastelloy alloy C (110°F) are among the few metals usefully resistant to  $\text{Cl}_2$  under wet condensate conditions. Temperatures indicated in the parentheses are suggested approximate upper limiting temperatures for service.

Titanium has shown excellent resistance to wet  $\text{Cl}_2$  at temperatures as high as 205°F (10). However, titanium can fail rapidly in dry  $\text{Cl}_2$  (containing less than 0.012%  $\text{H}_2\text{O}$ ) in the absence of sufficient water to maintain a passive film. Titanium may ignite in dry  $\text{Cl}_2$  under some conditions (14).

Small amounts of moisture in  $\text{Cl}_2$  also increase the corrosion rate of some metals, as compared with rates in dry  $\text{Cl}_2$ , at temperatures above the dew point and up to about 700°F. Brown, DeLong, and Auld (15) have

**Table 7.** Corrosion tests in tank holding monochlorobenzene containing traces of water and phenol. Temperature was 140 to 160°F and test ran 57 days.

MATERIAL	CORROSION RATE, IN./YEAR
Type 304 stainless steel	0.005 (perforated)
Type 316 stainless steel	0.007 (perforated)
85-5-5-5 Bronze	0.007
Inconel alloy	0.007
"A" nickel	0.008
Monel alloy	0.009
Copper	0.019
Ni-Resist cast iron	
Type 1	0.029
Mild steel	0.12
Cast iron	0.15

investigated high temperature corrosion of metals by chlorine.

## Corrosion by other halides

Much of the discussion has been centered so far on examining change in corrosiveness of some specific chlorohydrocarbons. The limited length of this presentation does not permit a detailed examination of the many other chloro-compounds that behave similarly. Some of the chloro-compounds to watch with regard to wet



Heat exchanger tube bundle of Carpenter Stainless No. 20 Cb for handling conc.  $\text{H}_2\text{SO}_4$  at temperatures of 175° to 194°F and pressures to 400 lb./sq. in.

corrosiveness include, for example: acetyl, allyl, amyl, benzyl, benzoyl, ethyl, ethylene, methyl, methylene, nitrosyl, propylene, sulfur, sulfuryl, and vinyl chlorides; phosphorus oxychloride; phosphorus and boron trichloride; silicon, tin, and titanium tetrachloride; chloroform; carbon tetrachloride; trichloroethane; trichloroethylene; tetrachloroethane; perchloroethylene; chlorobenzene; phosgene; and ethylene chlorohydrin.

Many derivatives of other members of the halides group may be found in the same category with respect to hydrolysis in the presence of water. Thus, the bromo and iodo compounds corresponding to many of the above chloro-compounds may also be added to the list for special attention. The hydrobromic and hydriodic acids formed by hydrolysis can be very formidable corrosives.

### Ammonia processing

Most metals are resistant to dry  $\text{NH}_3$  at ordinary temperatures and a number of them, including the aluminum alloys, stainless steels, and Inconel alloy are not affected by wet  $\text{NH}_3$  vapors or  $\text{NH}_4\text{OH}$  solutions over a wide range of conditions. Cast iron and steel have a tolerable resistance to wet  $\text{NH}_3$  at moderate temperatures but can not be used if iron pick-up via rusting is detrimental.

The presence of moisture in  $\text{NH}_3$  at temperatures below the dew point is particularly harmful to copper and its alloys, nickel-copper alloys, and nickel. Traces of water vapor and  $\text{O}_2$  in  $\text{NH}_3$  will cause fairly rapid attack of copper alloys. This combination may also produce stress corrosion cracking of many of the copper base alloys when a high level of residual or applied stresses exists in the metal. Traditionally, this cracking of copper alloys has been called "season cracking." The copper alloys containing more than 15% Zn are especially susceptible to this form of damage. Removal of residual stresses by stress relief annealing heat treatment prior to service has been helpful in avoiding the cracking phenomenon. The cupro-nickel alloys are superior to the other copper alloys in their resistance to corrosion attack and to stress corrosion cracking by moist  $\text{NH}_3$  or  $\text{NH}_4\text{OH}$  (15).

"A" nickel and Monel nickel-copper alloy can be appreciably corroded by condensed wet  $\text{NH}_3$ . Neither of the metals are suggested for service in which the concentration of  $\text{NH}_4\text{OH}$  solution exceeds 1.5% to 3%.

### Sulfur dioxide

In addition to use as a chemical

raw material,  $\text{SO}_2$  is encountered to a great extent in flue gases evolved during calcining of sulfur-containing chemicals and from the combustion of sulfur-bearing fuels.

Anhydrous  $\text{SO}_2$  gas or liquid poses no particular problem to common materials of construction. In the presence of water,  $\text{SO}_2$  readily dissolves

and forms  $\text{H}_2\text{SO}_3$  and the corrosiveness will depend on the extent of condensation and process conditions. The presence of  $\text{SO}_3$ , HCl or other acid forming compounds with  $\text{SO}_2$  will increase the severity of the attack by condensed acids.

Hot wet  $\text{SO}_2$  gas is not corrosive at moderate temperatures above the dew

Table 8. Corrosion tests in activated carbon solvent recovery system.

Solvent: 90% methylene chloride-10% methanol.  
Feed to adsorber: Vapor-laden air.  
Solvent 1% of vapor volume.  
Temperature: 100°F.  
Solvent saturated-carbon bed stripped by steaming.

MATERIAL	CORROSION RATE, IN./YEAR		
	IN FEED TO ADSORBER 100° F 87 DAYS	IN VAPOR ABOVE CARBON BED 100-212° F 25 DAYS	IN CARBON BED 100-212° F 25 DAYS
Carbon steel	....	0.019	0.025
Copper	0.0002	0.003	0.004
Monel alloy	0.0001	0.001	0.003
"A" nickel	....	0.0003	0.0008
Type 304 stainless steel	0.0003	0.004*	0.002*
Type 316 stainless steel	....	0.002*	0.001*
Hastelloy alloy B	....	<0.0001	0.001
Hastelloy alloy C	....	<0.0001	<0.0001

\*Stress corrosion cracking plus slight pitting attack

Table 9. Corrosion tests in activated carbon solvent recovery system.

Feed to adsorber condenser:  
Vapor of 2% methanol, 22% methylene chloride, 75% water.  
Duration of Test: 51 Days

MATERIAL	CORROSION RATE, IN./YEAR	
	IN VAPOR FEED TO ADSORBER CONDENSER (100-250° F)	LIQUID OUTLET FROM CONDENSER (100-140° F)
Carbon steel	0.24	0.059
Copper	0.019**	0.004**
Type 304 stainless steel	0.0008*	<0.0001
Type 316 stainless steel	0.0001*	<0.0001
Monel alloy	0.008	0.004
"A" nickel	0.005	0.008**
Hastelloy alloy B	0.007	0.017**
Hastelloy alloy C	0.0002	<0.0001

\*Stress corrosion cracked

\*\*Slight pitting attack

Table 10. Corrosion tests in activated carbon solvent recovery system.

A-Decanter water layer-98.5%  $\text{H}_2\text{O}$ , 0.5% methylene chloride, 1% methanol. Acidity: 0.007% as HCl.  
B-Decanter solvent layer-99.3% methylene chloride, 0.5% methanol. Acidity: 0.007% as HCl.  
Duration of test: 56 Days.

MATERIAL	CORROSION RATE, IN./YEAR	
	A-WATER LAYER 75-85°F	B-SOLVENT LAYER 75-100°F
Carbon steel	0.022	0.011
Copper	0.002	0.0004
"A" nickel	0.0008	<0.0001
Monel	0.002	<0.0001
Type 304 stainless steel	<0.0001	0.0001
Type 316 stainless steel	<0.0001	0.0003

point of the  $\text{SO}_2\text{-H}_2\text{O}$  mixture. Most of the difficulties arise during the handling of flue gases in scrubbers, precipitators, exhaust lines, and stacks where  $\text{SO}_2$  may combine and condense as an acid in cooler locations with water of combustion, atmospheric moisture, or washing waters. Tables 11 through 15 show the results of some field corrosion tests performed in  $\text{SO}_2$  environments.

The non-corrosiveness of an  $\text{SO}_2\text{-H}_2\text{O}$  mixture at temperatures above the dew point is evidenced by the low corrosion rates obtained for metals in Table 11. However, a unit operated above dew point temperatures is not always invulnerable to condensate corrosion. There would be opportunities for condensation and corrosion to occur during shutdown periods if precautions are not taken to purge the unit prior to cooling.

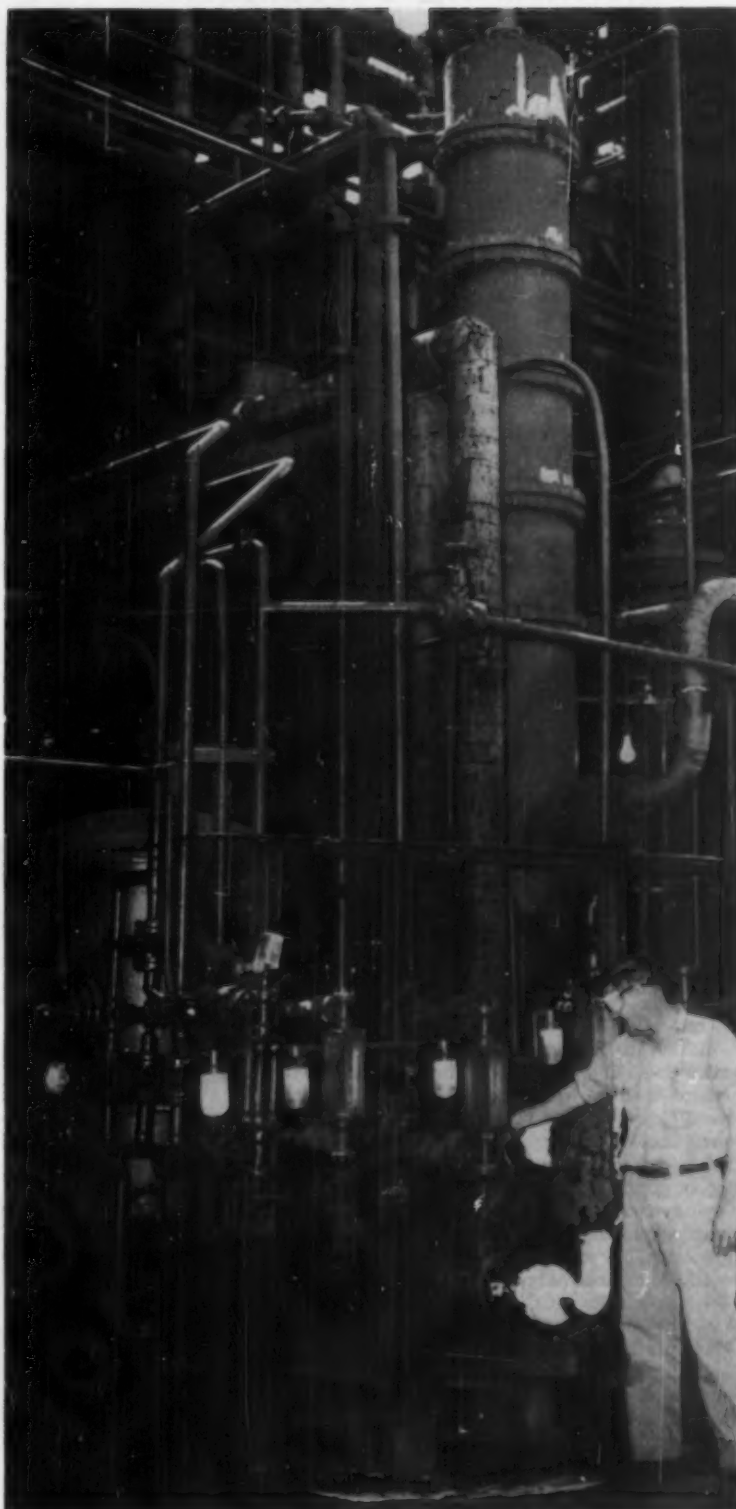
The more aggressive corrosive conditions existing when  $\text{SO}_2\text{-H}_2\text{O}$  mixtures are present below dew point temperatures are indicated in Tables 12 and 13. The austenitic stainless steels, Hastelloy alloy C, and lead demonstrated their good resistance to the  $\text{H}_2\text{SO}_4$  condensate. In the test (Table 14) conducted on the performance of stainless steels in a  $\text{SO}_2$  adsorption tower (17) the regular grades of chromium-nickel and chromium-nickel-molybdenum stainless steels were not adequately resistant and only the higher alloyed chromium-nickel-moly-copper "alloy 20" type stainless steel showed suitable resistance. Types 304 and 316 stainless steels were also attacked when  $\text{H}_2\text{SO}_4$  was also present in the recycle solution (Table 15).

The austenitic stainless steels are the most extensively employed metals for handling a wide range of  $\text{SO}_2\text{-H}_2\text{SO}_4$  conditions. Type 304 may be satisfactory for mild service but Type 316 and Type 317 are usually required for more severe applications at hot temperatures. When  $\text{H}_2\text{SO}_4$  is also found with  $\text{H}_2\text{SO}_3$ , the "20" grade of stainless steels or Ni-o-Nel alloy\* may be needed.

Aluminum and its alloys possess good resistance to wet  $\text{SO}_2$ -dilute  $\text{H}_2\text{SO}_3$  solutions providing chlorides and heavy metals are absent (18).

Lead provides a high degree of corrosion resistance to  $\text{SO}_2$  and its associated compounds. Despite mechanical property limitations, lead has been used over the years in a number of processes involving the handling of  $\text{SO}_2$ .

\* Reg. Trade Mark, The International Nickel Company, Inc.



Monel nickel-copper alloy equipment for handling moist carbon tetrachloride.



# Minimizing corrosion

Use these practical tips to extend equipment lifetime when processing wet corrosive media.

A knowledge of the mechanism of corrosive attack by wet chemicals is not very helpful if it is not applied to practical considerations for extending service life of process equipment. Some of the following steps may aid in combatting corrosion under wet conditions:

**Eliminate water.** The most obvious remedy is to keep water away from media that readily become corrosive. Unfortunately, this is more often easier said than done because of the difficulty of sustaining anhydrous conditions in process and storage systems. This would not apply, of course, in applications in which water or steam must be introduced into the system as a relevant part of the process. However, there are a number of steps that can be taken in the task of keeping moisture pickup to a minimum:

1. All joints and connections in process piping and vessels should be kept tight and leak-proof to prevent leakage of steam, cooling water, or atmospheric moisture into the process system. Careful attention should be paid to selection, condition, and performance of gaskets.

2. Units should be kept closed during shutdown periods to prevent entrance of atmospheric moisture. Purging with inert dry gas such as air or  $N_2$  prior to or during shutdown is helpful in sustaining a dry atmosphere.

3. Use a desiccant cartridge or cartridge-relief valve combination on storage facilities where air may enter during discharging operations or where continued changes in atmospheric conditions produce "breathing" or exchange of moisture-laden air. Drying agents such as silica gel or dehydrated alumina are effective desiccants. For example, a pitting-type attack on the internal welds of a Type 304 stainless steel  $CCl_4$  storage tank was attributed to HCl formed by reaction of atmospheric moisture with the  $CCl_4$ . A desiccant cartridge placed on the tank vent line was sufficient to prevent further occurrence of pitting.

4. Washing out storage or process equipment handling easily hydrolyzed compounds with steam or water should be avoided or carefully con-

trolled. For example, a steam purge of a nickel pipeline conveying benzyl chloride left a residue of nickel chloride corrosion product on the pipe wall. The next batch of benzyl chloride showed evidence of discoloration as a result of nickel pickup. Conversely, an aluminum tank was washed out with a chlorinated solvent and allowed to stand empty. Moisture picked up from the atmosphere reacted with the solvent remaining on the metal surface and caused corrosion of the tank wall and bottom.

The necessity for keeping moisture out of bromine shipping drums, even when constructed of Monel alloy, is stressed repeatedly by bromine producers. The instructions call for no water washing of emptied drums prior to return shipment. Instead, directions advise prompt replacing and tighten-

ing of plugs as soon as the drum is emptied. A drying cartridge is used on vent lines during unloading by siphon procedure. Air used for pressure unloading is passed through driers.

5. Use water separator and traps to prevent accumulation of water layers.

6. Use dry raw materials. The starting process materials should be in an essentially dry state to eliminate them as possible sources of moisture.

**Add inhibitors or stabilizers.** An inhibitor, as applied to corrosion, is a chemical substance that markedly reduces corrosion when added in small amounts. Despite limitations on their effectiveness under some operating conditions, inhibitors may offer a degree of corrosion protection during the handling of chlorohydrocarbons.

A number of producers of chlorohydrocarbon dry cleaning solvents add various formulations of stabilizers to their proprietary solvents. Some of these are based on alkaline amine compounds and others on acetylenic HCl-acceptor compounds. By forming a protective film on the metal surface and so preventing metal pickup that would exert a catalytic action on the decomposition of chlorohydrocarbon,



Figure 1. Corroded nozzle from column used to process ethylene chlorohydrin.



**Table 11.** Corrosion tests in gases containing 2% to 5% SO<sub>2</sub> and saturated with water vapor. Temperature was 450°F and test ran 180 days.

MATERIAL	CORROSION RATE, IN./YEAR
Type 304 stainless steel	< 0.0001
Type 316 stainless steel	< 0.0001
Carpenter 20*	< 0.0001
Ni-o-nel**	< 0.0001
Monel alloy	0.0002
Mild steel	0.002
Cast iron	0.004

\*Nickel-iron-chromium alloy produced by Carpenter Steel Co.

\*\*Nickel-iron-chromium alloy produced by The International Nickel Co.

**Table 12.** Corrosion tests in gases containing 13% to 17% SO<sub>2</sub> saturated with water vapor. Temperature was 100°F and test ran 37 days.

MATERIAL	CORROSION RATE, IN./YEAR
Type 304 stainless steel	< 0.0001
Type 316 stainless steel	< 0.0001
Type 430 stainless steel	> 0.15
Monel alloy	> 0.15
"A" nickel	> 0.16
mild steel	> 0.31
Inconel alloy	0.007
chemical lead	0.002

the inhibitor in effect acts as a stabilizer. Alkalies can be added to neutralize any HCl formed by hydrolysis and, in this way, inhibit corrosion.

In their studies on the use of inhibitors for preventing corrosion of steel in a CCl<sub>4</sub>-H<sub>2</sub>O vapor system, Calkins and Hawley (4) reported that 2-aminoethanol (monoethanolamine) showed promise as an inhibitor in that system at room and 50°C temperatures when present in amounts greater than saturation.

Other examples include stabilizing benzoyl chloride with lime or sodium bicarbonate when shipped or stored in steel equipment. However, an extra processing step is eventually required to remove the stabilizer. Also, caustic soda was employed at one plant to protect a steel column by neutralizing any HCl formed by the decomposition of a chlorinated hydrocarbon. The cure was almost fatal in that a sufficient amount of caustic was concentrated in crevices to cause stress corrosion cracking (caustic embrittlement) of the column in the vicinity of cap trays.

Maintain temperature above dew point. Corrosion by acid condensates can be prevented by sustaining the metal wall temperature above that required for condensation of aqueous acid solutions. Friend and LaQue (19) cited a case where corrosion of a 24-in. cast iron pipe, carrying SO<sub>2</sub>

**Table 13.** Corrosion tests in fumes containing 5% SO<sub>2</sub>, 8% CO<sub>2</sub>, 11% O<sub>2</sub> and SO<sub>2</sub> mist from calcining operation. Temperatures 40°-130°F, flow was 3000 ft./min. and test ran 34 days.

MATERIAL	CORROSION RATE, IN./YEAR
Hastelloy alloy C	0.0001
Type 316 stainless steel	< 0.0001
Carpenter 20 alloy	< 0.0001
Chemical lead	0.001
Inconel alloy	0.017
Monel alloy	0.073
"A" nickel	> 0.16
Ni-resist type 1 alloy	0.88

**Table 14.** Corrosion test in adsorption tower with SO<sub>2</sub> gas saturated with water vapor. Temperature was 90°F and test ran 20 days.

MATERIAL	CORROSION RATE, IN./YEAR
Carpenter 20 alloy	0.002
Type 317 stainless steel	0.015
Type 316 stainless steel	0.030
Type 304 stainless steel	0.15

**Table 15.** Corrosion tests in SO<sub>2</sub> gas scrubbing with 10% SO<sub>2</sub> saturated with water and recycle liquor contained 1.44% H<sub>2</sub>SO<sub>4</sub>. Temperature was 135°F and test ran 20 days.

MATERIAL	CORROSION RATE, IN./YEAR
Ni-o-nel alloy	0.002
Carpenter 20 alloy	0.003
Hastelloy alloy C	0.003
Chemical lead	0.005
Type 317 stainless steel	0.006
Type 316 stainless steel	0.050
Hastelloy alloy B	0.077
Type 302 stainless steel	0.25
Monel alloy	0.32

from sulfur burners to coolers, was reduced when the pipe was covered with asbestos insulation to keep internal surface temperature above the dew point. Not only was corrosion retarded by this step but the lagged pipes also gave a better performance as preliminary coolers than the bare pipe. The thick layers of iron sulfate formed as corrosion product had been more of a hindrance to heat flow than the exterior insulation.

Figure 1 shows a Monel nickel-copper alloy nozzle after short exposure dead-ended by a closed valve on a tower handling 99% ethylene chlorohydrin with about 0.01% H<sub>2</sub>O and 0.2% acidity as HCl at 155°F. Note the channel corroded out on the inside surface and at the flange as a result of allowing acid condensation to occur on the cooler surface of the nozzle.

Operate at lower temperature. Appreciable decomposition of the more stable wet chlorohydrocarbons, that tend to hydrolyze at or above the

boiling point, may be avoided by operating at lower temperatures.

### Select suitable materials

The judicious selection of corrosion resistant materials of construction is perhaps the most important and most reliable factor in minimizing attack by wet corrosives. This accounts for the amount of space in this article devoted to the corrosion-resistant properties and behavior of a number of metals and alloys in wet corrosive environments.

The previously mentioned methods of mitigating attack by wet corrosives are often helpful but are limited in their over-all effectiveness. When it is necessary to protect product purity by guarding against metallic contamination or when the wet corrosives are encountered under conditions of strong corrosive activity, the properly chosen resistant metal or alloy offers the best solution to the problems. This is substantiated by the large tonnages of such alloys now in use in petrochemical plants to combat wet corrosive environments.

The old admonition "keep your powder dry" saved many from surprise attack. The same warning, paraphrased "keep your process conditions dry," is still applicable under certain conditions of petrochemical processing but against a different type of attack. However, slogans and battle cries are not usually enough in the fight against corrosion unless backed by the prudent choice of suitable materials of construction.

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## Design and operating tips for Ethanolamine gas scrubbing systems

Use these recommended design and operating procedures to minimize corrosion problems in  $H_2S$  and  $CO_2$  absorption plants.

THERE ARE TWO TYPES of plants commonly utilizing the ethanolamines as acid gas absorbers. The Girbitol process employs a relatively dilute solution of either monoethanolamine or diethanolamine. The Fluor process generally uses a mixture of MEA and diethylene glycol with approximately five per cent water. While the latter process provides simultaneous dehydration and acid gas removal, the dew point depressions normally obtained are  $50^\circ F$ , or less, thus limiting its application to areas having moderate winter climates. The aqueous, or Girbitol, process herein discussed is the most widely used method in North America for removing carbon dioxide and/or hydrogen sulfide from refinery gases and liquids, natural gases, stack gases and chemical plant synthesis gases.

Briefly, the Girbitol process is a simple cyclic one wherein a lean amine solution is contacted with the sour gas in a tray or packed absorber at temperatures ranging from  $60^\circ F$  to  $140^\circ F$ , usually at moderate to high pressure although carbon dioxide removal systems frequently operate at atmospheric pressure. The rich amine leaving the bottom of the absorber is heat exchanged with the hot lean solution from the reboiler, reduced in pressure, and regenerated in a plate or packed type still. The increase in temperature to  $220$ – $250^\circ F$  in the still reverses the absorption reaction and most of the acid gases are removed through the reflux con-

denser (Figure 1). Further details of the process are available from the literature (1, 2).

The Girbitol process has been in use since the 1930's. Through the years much has been learned about plant design and methods of minimizing operating problems so that today most plants provide relatively trouble-free operation. However, plant personnel still come up against operating problems. Those most commonly encountered are discussed here.

### Foaming, its cause and control

Contaminants in the solution cause foaming. Frequently only a small increase in their concentration is needed to precipitate a sudden severe

foaming problem. The contaminants most frequently encountered are liquid hydrocarbons, suspended solids, and dissolved foreign compounds (which may be amine degradation products). When foaming is first encountered, simple laboratory studies should be undertaken to find an effective antifoam agent. The laboratory is suggested rather than the plant since the selection of the proper agent is not a science. A product that works well in one plant may be ineffective in a second or even promote foaming. The most commonly used antifoam agents are long chain aliphatic alcohols, certain synthetic lubricants, silicones, and phosphate esters. Usually a batch addition of antifoam agent is sufficient, but some plants require a continuous or daily addition. Once the foaming is under control so that the plant can operate satisfactorily, the source of the trouble should be investigated. If the cause is found to be the condensation of hydrocarbons in the absorber, its temperature should be increased  $10^\circ F$  above the inlet gas temperature, and the operation of the inlet entrainment separator examined to make certain that liquids are not entering the system with the gas phase. Suspended solids can be removed by a filter or reclaimer while dissolved foreign materials can be eliminated by a re-

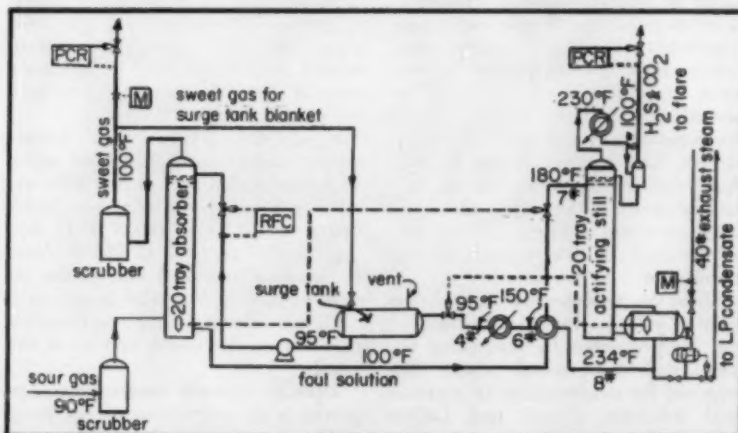


Figure 1. Simplified flow chart, Girbitol process.

claimer or activated carbon adsorber.

### Degradation affects selection

Degradation or inactivation of the ethanolamines may be caused by their reaction with carbon dioxide, carbonyl sulfide, cyanides, oxygen, and acids stronger than  $H_2S$  and  $CO_2$  or excessively high temperatures. In 1955 and 1956 the mechanism of MEA and DEA degradation was fully outlined (3, 4). The presence of degradation products in the circulating solution can lead to foaming, increased corrosion rates, reduced acid gas absorption capacity, and increased solution viscosity.

If "strong" acids or cyanides are present in the sour gas stream, a water or spent caustic wash system should be considered since they are being economically used to remove these compounds in some plants. If practical, oxygen should be excluded by an inert gas blanket on all surge vessels. No way is known today of economically removing carbonyl sulfide in a pretreatment, or preventing its reaction with, and subsequent degradation of, MEA. Diethanolamine is frequently selected for refinery use as it is not degraded by carbonyl sulfide, a common constituent of many sour gas refinery streams, and is less soluble than MEA in liquid hydrocarbons. Diethanolamine finds little use outside refineries since it has considerably less acid gas absorption capacity per pound, and its recovery from fouled solutions is more difficult than MEA.

### Tips on designing reclaimers

While MEA reclaimers have been in service for many years it has not been until the last five that they have been widely used and detailed suggestions for their operation have only recently been published (1, 11). The following recommendations for reclaimer design are proposed:

1. Design the reclaimer to handle one percent of the circulating solution and more if degradation is expected or known to be excessive or if there is no filter.

2. The kettle should have a liquid capacity in gallons of approximately one hundred times the feed rate in gals./min.

3. Stress-relieved carbon steel is satisfactory for the kettle body, and also in most cases for the tubes, especially if heat stable salts are properly neutralized in the reclaimer. Sodium carbonate is normally recommended to neutralize the "strong" acid portion of the heat stable salts. If stainless steel tubes are used, Rayon or Mercury cell grade caustic, or "low salt" or natural soda ash should be used to prevent chloride attack.

4. A U-tube bundle is satisfactory. Design for a high fouling factor and use a wide tube spacing for easy cleaning. Keep the bottom of the bundle 12-in. above the bottom of the shell. Have an easy-to-open manway on the shell so that solids can be simply washed out of the reclaimer at the end of the cycle. Make the drain line large enough to

pass solids, a minimum size of 2-3 in. is suggested.

5. Provide a soda ash mix tank and a coupling in the reboiler shell for the addition of the neutralizing solution during the cycle.

6. Supply a short column section on top of the kettle and pack it with ceramic rings or a demister pad to eliminate foam and entrainment from the overhead vapor stream. If the overhead vapors are fed directly into the regeneration still, install a look-box in the vapor line to make certain that foam or entrainment does not re-enter the system.

7. Provide a steam sparger pipe below the bundle and weld clips over the holes to prevent erosion of the tubes or shell by the steam. Steam condensate may also be used.

8. Control the feed to the reclaimer by a level controller on the kettle and maintain a liquid level at least six inches above the top of the tube bundle at least during the equilibrium period. Install a rotameter in the feed line to indicate when the feed falls off and steam stripping should be started.

9. Have a chart recording the reclaimer temperature throughout the cycle. A 7 or 14 day chart is suggested.

10. The maximum reclaimer temperature should be 300-310°F — make certain the steam supply is not superheated.

A reclaimer designed in this fashion and properly operated will effectively remove degradation products and solids from the circulated solution even when it is abused.

### Sludge accumulation problems

The sludge found in ethanolamine acid gas removal systems usually consists of iron sulfide or carbonate which enters with the gas being treated or results from corrosion of the equipment itself. The sludge most frequently accumulates in the heat exchangers, reboilers and on the still trays or packing. Sludge accumulation may cause severe localized corrosion, reduced tray or packing efficiency, and poor heat transfer. The accumulation of sludge usually is traceable to poor solution filtration. If contamination occurs slowly, it may be possible to remove solids by means

**Girbitol process** where ethanolamine solution is used to scrub  $H_2S$  and  $CO_2$ .





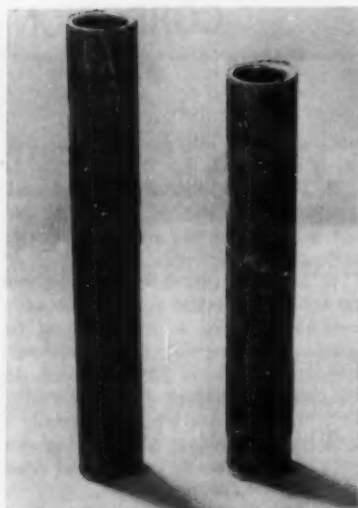


Figure 2. Pits occurred circumferentially at edge of area where tubes were inserted in reboiler baffle.

of a reclaiming only. In severe cases a 10% side stream of the circulated solution should be continuously filtered through a filter capable of removing particles down to two microns. A wire screen type filter with precoat facilities is proposed for larger plants.

#### Failure to sweeten effluent gas

Since MEA and DEA have a high affinity for  $H_2S$  and  $CO_2$ , failure to effectively remove these compounds can generally be traced to inadequate contact between the gas and liquid streams because of foaming or mechanical difficulties with the contact surface, or lack of solution acid gas absorption capacity. If a sweetening problem is encountered the operator should first check the solution circulation rate and strength to determine if sufficient free amine is available. Monoethanolamine systems should be able to sweeten gas at high loadings, even above 0.6 or 0.7 mol acid gas/mol of amine under certain conditions. Low, active, or free amine content is usually due to:

1. poor regeneration;
2. a portion of the amine being combined with acids in the form of heat stable salts;
3. degradation of the amine.

Regeneration should be accomplished to an acid gas level of 0.1 mol acid gas/mol of amine or less in MEA- $CO_2$  systems and lower with DEA or straight  $H_2S$  removal systems. Poor regeneration is usually due to inadequate steam consumption in the reboiler (1.0 lb./gal. of solution circulated is adequate in most plants),

plugging of trays or packing in the still, channeling through the packing, or corrosion of the trays. In systems where there is no  $H_2S$ , or the  $H_2S$  to  $CO_2$  ratio is low, a pressure of 15 to 20 lb./sq. in. gauge in the reboiler with a resultant reboiler temperature of 245-255°F (at sea level) is required to obtain good regeneration. Lower temperatures and pressures are satisfactory in  $H_2S$  systems.

#### Corrosion problems inconsistent

While corrosion problems are severe in some amine-type gas treating plants, others experience little or only mild attack. In many cases, severe corrosion can be traced to operational or design factors. Overloading the equipment is probably the most frequent cause of serious corrosion. The items of equipment most generally attacked are heat exchanger and reboiler tube bundles and regeneration stills. Corrosion is likely to be most severe in MEA systems removing only  $CO_2$  since mixtures of  $H_2S$  and  $CO_2$ , and  $H_2S$  alone, are progressively easier to handle with the materials of construction used. Severe corrosion is not frequently encountered in DEA systems.

#### Laboratory—plant corrosion tests

Laboratory studies show that a new 20 percent MEA solution in water is less corrosive towards carbon steel than is water alone, while in the presence of  $CO_2$  and/or  $H_2S$  the rates of attack in the liquid phases are approximately equal. In the vapor phase, the presence of MEA in the solution reduces the penetration to about one tenth of that found with straight water. Increasing temperature promotes attack of carbon steel in the liquid phase in the presence of the acid gases. Table 1 shows plant corrosion data on coupons exposed in an MEA reboiler handling a 20

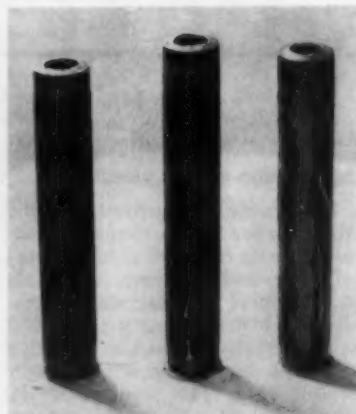


Figure 3. A light gray to dark scale was present on all reboiler tubes.

percent MEA solution at 230°F. The system is used to remove  $H_2S$  from fuel gas. Types 304 and 316 stainless steel, and Hastelloy F, showed no corrosion. It is probably impossible to duplicate tube corrosion with test coupons as the tubes are internally heated while the coupons are not.

Table 1. Plant corrosion data on coupons.

	Penetrations, IPY	
	First Exposure	Second Exposure
	2600 hours	5000 hours
Carbon Steel	.010	.008
5% Chrome Steel	.007	.002
304 Stainless	Nil	Nil
316 Stainless	Nil	Nil
Hastelloy F	Nil	Nil
Admiralty B	Nil	.003
Monel	Nil	.001

Copper and its common alloys, excluding Monel and similar alloys, are not generally recommended for amine service despite low penetrations found in laboratory and plant studies. The presence of  $H_2S$  in the test environment reported, produced a protective film. Brass has served satisfactorily in some still condensers where the amine concentration is under 0.5% in the condensate.

The corrosiveness of amine solutions to various metals has been reported by Lang & Mason (5) and others.

In general, many laboratory studies indicate that amine solutions are not seriously corrosive and when severe penetration rates are encountered in a plant, either operating practices, faulty design, or serious solution contamination will generally be found to be the cause. The newer type electrical resistance type corrosion meters are recommended for monitoring the

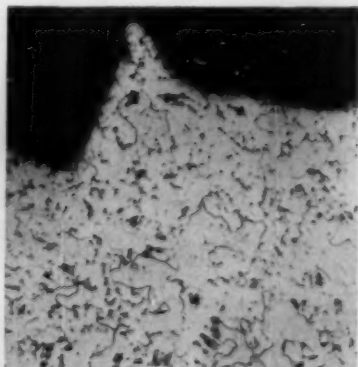


Figure 4. Cross-sectional view of tube with cut made through pit.



corrosive characteristics of plant solutions (6, 10) at regular intervals.

An API study showed (12) that inhibitors were used in 16 of 39 amine type plants studied: 8 of 12 monethanolamine plants and 8 of 27 diethanolamine plants using filming type inhibitors. Of the 39 cooperating plants, 11 reported existing problems. Reboiler tube corrosion was shown to be the most common difficulty. The detergent action of the inhibitors used resulted in cleaner equipment and thus probably further reduced corrosion as iron sulfide deposits can accelerate pitting type attack.

We and others have tested many inhibitors. It is felt that plant trials are necessary to evaluate their effectiveness where corrosion problems persist. Corrosion test meters greatly simplify such an evaluation. Some inhibitors promote foaming and this effect should be investigated in the laboratory before the inhibitor is added to the plant solution. The compatibility of the inhibitor with any anti-foam agents used should also be tested.

## Case Histories

An outline of a few corrosion case histories will show the importance of some factors in minimizing corrosion problems.

### Plant No. 1

#### Operating Conditions:

- Inlet gas flow—200 MMCF/day
- Acid gas composition—28.5% CO<sub>2</sub> (trace H<sub>2</sub>S)
- Amine circulation—14,000 gal./min. of 16% MEA
- Regeneration—265°F. at 22 lbs./sq. in. gauge
- Steam temperature—285°F. and saturated
- Steam consumption—1.25 lbs./gal. of circulated solution
- Average rich solution loading—0.45 mol. CO<sub>2</sub>/mol. of MEA
- Average lean solution regeneration—0.07 mol. CO<sub>2</sub>/mol. of MEA

Severe corrosion of the still reboiler tubes has existed until recently, and corrosion has also been encountered in the heat exchangers, bubble caps and bubble cap "J" bolts, motor valves and rich solution piping. During early operation of the plant, filtration efficiency was poor and severe heat exchanger tube plugging occurred. The high concentration of suspended solids contributed to erosion of the heat exchanger equipment and motor valves, and added to the deposition of corrosive sludges in the heat exchangers. The

sludge was found to be stabilized, or bound, by a long chain aliphatic alcohol used in large quantities as an antifoam agent. While attack of the type 304 stainless steel motor valves was aggravated by the presence of suspended solids in the solution, the main cause of failure was attributed to excessive velocity through the valve body. Fluid velocity through the motor valve bodies in this plant are now held to 15-20 ft./sec.

Still bubble caps in some of the stills were first constructed of 16BWC type 410 stainless steel, and most of the caps on the 9 to 20th trays were severely corroded. There was no sign of corrosion of the trays to which the caps were tack welded. Corrosion was attributed to galvanic action of the 410-to-steel couple, with cathodic reduction of the normally passivating oxide film adjacent to the couple. There was also some general thinning of the caps, but failure was attributed to the galvanic action. Mechanite E cast iron caps used to replace the original caps have given much better service.



Figure 5. Severe corrosion of 304 stainless occurred near top of the tower opposite the feed inlet.

Rich solution lines were field welded and consequently not stress-relieved. Pin-hole leaks developed, and welded patches were required.

The most serious corrosion encountered has been in the reboiler tube bundles. In one year it was necessary to replace nearly 27,000 tubes. Examination of tubing sections showed each contained isolated pits with little evidence of corrosion in other areas. With few exceptions the pits were confined to one side of the tube rather than scattered randomly over the surface. However, on some tubes pits occurred circumferentially at the edge of an area where the tubes were inserted in the baffle (Figure 2). Some of the pits appeared to have originated at surface flaws or defects (Figure 3, middle tube). A light gray to dark scale was present on all of the tubes (Figure 3, third tube).

The scale contained large amounts of iron carbonate, and smaller amounts of iron oxide (Fe<sub>2</sub>O<sub>3</sub>). The appearance of the tube at a cross-section through the pit is shown in Figure 4.

The micro structure of the steel was found to be normal. The structure consisted of ferrite and spheroidized carbides which is the type of structure normally developed in this type of steel to obtain optimum fabricating properties. However, there are a number of references in the literature indicating that the form and distribution of carbides in low carbon steel have some effect on its corrosion resistance (7, 8, 9). It is pointed out that the spheroid structure is detrimental. As far as we know, no work has yet been undertaken to determine if the micro structure of the steel may be a factor in its behavior in ethanolamine systems.

While some corrosion is still being encountered, several changes in plant operation have been made over the years which have significantly reduced the problem. These include a reduction in the solution loading, modification of the reboiler design, and improved solution filtration and reclaiming. More recently, soda ash in low concentrations has been added directly to the circulating solution to neutralize heat-stable amine salts. This appears to have further reduced the quantity of sludge accumulating in the heat exchanger and reboiler tube bundles. Recently a dry desiccant type hydrocarbon absorption plant has been installed upstream of the amine units to remove liquid hydrocarbons that were contaminating the amine system. Since this unit has been installed, foaming has decreased and corrosion has been further reduced. The quantity of soda ash required to neutralize heat stable salts has also been lowered and it therefore appears that organic acids or other contaminants adversely affecting the amine were entering the system from the field.

The most interesting recent change has been the addition of cathodic type protection to two reboilers. The cathodic protection is supplied by Duriron electrodes immersed in the reboiler liquid between the two bundles. The electrodes have not dissipated as one might expect but have increased to about three times their original diameter. In the reboilers with cathodic protection, eight tubes have been replaced this year while in the unprotected units 300-400 tubes have been replaced or plugged. The tests have not been under way long enough to determine definitely

whether or not the cathodic protection is solely or partially responsible for the reduction in corrosion.

The performance of this plant has greatly improved in the past year or two; both corrosive attack and amine losses having been greatly reduced. The improvement since initial operation is not due to any one factor but rather to the combined effects of equipment and operating revisions, better solution control, and careful operating practices.

#### Plant No. 2

**Operating Conditions:** Inlet gas flow rate—0.875 MMCF/day

Acid gas composition—19% CO<sub>2</sub>

Amine circulation—40 gal./min. of 21% MEA

Regeneration—265°F. at 25 lbs./sq. in. gauge

Rich solution loading—0.45 mol. CO<sub>2</sub>/mol. of MEA

This small MEA plant is used to remove carbon dioxide from a hydrogen stream in a chemical plant. Corrosion has been experienced in the hottest heat exchanger, reboiler tube bundle, and the top two-thirds of the still column. Corrosion of the heat exchanger and reboiler bundle limited the life of the initial bundles to four years. After their failure, type 316 stainless steel bundles were installed and there has been no visible attack on the replacement heat exchange surfaces.

The still column is a three-foot diameter packed vessel. Originally it was constructed of stress-relieved carbon steel. During installation it was necessary to weld support lugs to the outside of the tower and these areas were not stress-relieved. In three years of service severe pitting occurred at the welds. The top two-thirds of the tower was removed and replaced with a type 304 stainless steel section, not stress-relieved. Severe corrosion of the 304 stainless occurred near the top of the tower opposite the feed inlet (Figure 5). It was necessary to replace the stainless in less than two years. A stress-relieved carbon steel tower has now been installed and shows no sign of corrosion after six months. It is possible that the design or operation of the plant resulted in unusually corrosive conditions near the top of the tower and stress-relieving of type 304 is recommended. Type 304 stainless has failed in some plants generally because of the presence of chlorides or lack of heat treatment. In field tests in one of our 25% MEA systems we observed corrosion rates of 9, 12 and 15 mils per year on steel, 10% chrome steel and type 304 respectively. These rates were

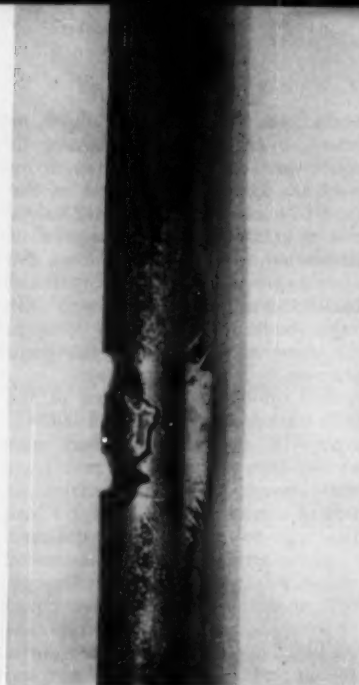


Figure 6. Differential thermal expansion between top and bottom sections of the bundle may have also contributed to severe "baffle-cutting" observed.

obtained on samples electrically insulated from one another.

#### Plant No. 3

**Operating Conditions:** Acid gas flow rate—17 MMCF/day

Acid gas content—25% CO<sub>2</sub>

Amine circulation—1100 gal./min. of 17% MEA solution

Regeneration—240° at 5 lbs./sq. in. gauge

Rich solution loading—0.4—0.45 mol CO<sub>2</sub>/mol MEA

Lean solution loading—less than 0.1 mol CO<sub>2</sub>/mol MEA

A 17% solution of MEA is used to remove CO<sub>2</sub> from an ammonia synthesis gas stream. Type 304 welded 16 BWG stainless steel tubes were used in all of the heat exchangers and reboilers, the heat exchangers were provided with stainless heads and the reboiler shells were stainless clad. Despite the extensive use of stainless steel, appreciable corrosion has been encountered. Corrosion has been most severe in the hottest heat exchangers on the lean side. Within two years after start-up, failures occurred primarily at the welds. Later, pin-hole leaks developed at points other than the welds. Corrosion and general thinning of tubes adjacent to those leaking was attributed to the impingement of the rich solution (at 290 lb./sq. in. gauge) on the outside of thinned tubes. The original tubes were not cold drawn and annealed. Metallurgical exami-

nation of the tubes in our laboratory has indicated that the original failures were due to porosity or inclusions in the welds. There was galvanic action between the active stainless in the pit and the surrounding passive surface, but there was no bi-metallic couple involved. The galvanic action was the result of the inclusions, and could not truly be called the cause of the failure. The original heat exchanger bundles have been replaced with new 16 BWG type 304 stainless steel tubes that were cold drawn, annealed and pickled. After nearly one and one-half years of service none of the new tubes have been replaced and no weld failures have been encountered.

We feel that welded tubing is satisfactory in amine treating plants, provided the tube is cold drawn after welding to effect a 35% reduction in area. This works out and tests the weld very thoroughly. The tube should then be fully annealed. Such tubes are considered equivalent of seamless tubing. Chemical analysis of the solution at the time the failures were occurring showed a high concentration of suspended solids, and high loadings in both the rich and lean solutions. Chlorides were present in the reclaimer residues at a concentration of 770 p.p.m. calculated as sodium chloride. Qualitative laboratory corrosion tests showed little liquid phase corrosion but rather heavy vapor phase corrosion including pitting of the metal, thus indicating the presence of volatile materials (in addition to CO<sub>2</sub>) promoting corrosion. It is believed that these contaminants were recirculated from the reclaimer to the plant solution and the addition of soda ash to the reclaimer was suggested to neutralize any volatile acids that might be present.

The suspended solids were found to consist primarily of carbon and iron oxide entering with the gas stream. The solids deposited on the outside (lean side) of the heat exchanger tubes and contributed to the corrosion. Improved operation, including closer control of solution loadings, better filtration, proper reclaimer performance, and the addition of soda ash to the reclaimer, have all contributed to a reduction in the rate of corrosive attack.

#### Plant No. 4

A 25-30% solution of DEA is circulated at the rate of 2,075 gal./min. to remove H<sub>2</sub>S from refinery gases and a liquid propane-butane stream. Regeneration of the solution is now accomplished at 242°F at 12 lbs./sq. in. gauge with 260°F steam. The plant

originally was designed to use a 20% solution of DEA and a solution loading of 0.62 mol acid gas/mol DEA. The 13-gauge carbon steel reboiler tubes were perforated at the baffles in the top half of the bundle after only ten months of operation. Superheated steam at 350°F. and 45 lbs./sq. in. gauge was originally used and the steam flow rate controlled by a valve on the condensate outlet causing the bundle to remain half full of condensate. This led to abusively high surface temperatures in order to obtain high heat transfer rates in the top of the bundle. The point of maximum thermal abuse of the amine is the crevice between the tubes and the baffles (and tube sheet when the tubes are poorly rolled). Concentration of contaminants should also be expected at these points. Differential thermal expansion between the top and bottom sections of the bundle may also have contributed to the severe "baffle-cutting" observed (Figure 6). Since changing the steam control valve to the steam supply line and desuperheating the steam, reboiler life has been extended to over two years despite the initial attack.

Stress corrosion cracking was encountered on the steel yokes which hold the risers and bubble caps in place on the regenerator trays. Stress-relieved type 304 yokes were used to replace the original yokes and no further problem has been encountered.

Studies were made to determine if a correlation existed between the rate of corrosion, the solution loading and the concentration of contaminants. Excellent data were obtained (10) using a corrosion test meter to show that the rate of corrosion in the absorber bottom and in the rich solution piping increased when the solution loading was raised above 0.34 mols of acid gas/mol of DEA, even though it was necessary to raise the concentration to 30 percent to get the loadings below this level. Penetration rates up to 36 mils per year were indicated by the probe. At loadings less than this little or no corrosion was indicated. It was found that the presence of thiocyanates and degradation products, at concentrations of over two percent in the lean solution, had a marked influence on corrosion, probe values showing attack at the rate of 40 mils per year. While the rates obtained are probably valid only for this particular plant, and only as an index rather than being quantitatively accurate, they confirm maximum solution loadings and contaminant concentrations recommend-

ed for several years as upper safe limits. The data also show a test meter can be a useful tool in monitoring corrosion.

Another interesting example of corrosion occurred in two carbon dioxide removal systems and is shown in Figures 7 and 8. Corrosive attack appeared in the form of both general thinning and pitting. The pitting was characterized by a distinct undercutting of the non-corroded areas, giving an appearance of porosity. The solution was slightly over-loaded in one system, and seriously in the second, while temperatures were excessively high in both, resulting in conditions of temperature and velocity inherently corrosive to mild steel. The unusual appearance of the steel, with its islands and pits, is due to the discontinuous nature of the protective film formed by corrosion, with the result that small cathodic areas are unaffected while adjacent anodic metal is corroded away. These photographs are typical of the type of attack found in carbon dioxide removal systems.

Corrosion problems encountered in natural gas treating plants containing hydrogen sulfide can occur in any of the ways indicated above, although the isolated pin-hole type pitting seldom occurs when hydrogen sulfide is present. Figure 9 shows the type of over-all pitting that most frequently occurs when corrosion problems are encountered in amine-type acid gas removal systems where  $H_2S$  is present. Some baffle-cutting of the tube is also evident.

#### Construction materials guide

Normally, carbon steel equipment is satisfactory in both MEA and DEA service, but stress-relieving of all major process equipment is important. Where experience indicates an unsatisfactory short life for carbon steel tubes, and plant operating practices cannot be revised to reduce the corrosiveness of the environment, the use of corrosion resistant alloys is indicated. Experience indicates that type 316 stainless steel is most satisfactory, while type 304 stainless gives good service at lower cost in most cases. It should be noted that there are some cases on record where type 304 failed rapidly. It is desirable to expose test tubes of both types 304 and 316 in a bundle before selecting either material. The tubing should be purchased in the annealed condition. Either seamless or welded tubing may be used, the latter being somewhat less expensive.

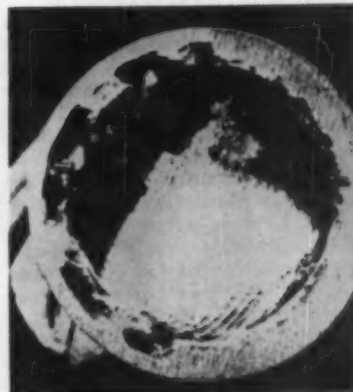


Figure 7. Corrosive attack appeared in the form of both general thinning and pitting.

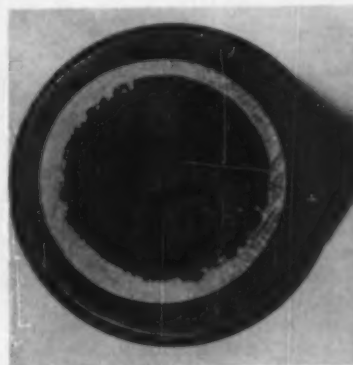


Figure 8. Pitting was characterized by distinct undercutting of non-corroded areas giving appearance of porosity.



Figure 9. This type of over-all pitting occurs most frequently when corrosion problems are encountered in systems where  $H_2S$  is present.



The process of rolling the tubes into the tube sheet does not generally set up sufficient cold work stresses to require heat treatment. If difficulty is experienced in securing tight tube sheet to tube seals, the tubes must be welded in place. If the tube bundle is of the hairpin type, it must be stress-relieved after fabrication to eliminate stress corrosion cracking of the cold worked areas. With floating head type bundles (no cold working or welding), heat treatment following fabrication is not required.

### Design and operating procedures

A review of recommended design and operating procedures may be helpful to minimize corrosion problems:

1. Hold solution loadings relatively low, preferably less than 0.4 mol acid gas/mol MEA in the rich solution. Therefore do not design for more than 0.33 mol acid gas to be accepted/mol MEA. Higher solution loadings can be used if stainless steel or other alloys are provided.
2. Use a low concentration of MEA, not over 20%. Diethanolamine strength can be as high as 30%. Low concentrations will result in lower losses, usually less corrosion, and greater flexibility should acid gas concentrations increase at some future date.
3. If it is found that contaminants are entering with the liquid or gaseous streams to be treated, it may be possible to significantly reduce solution fouling by pre-washing the offending streams with water, or a dilute soda ash or spent caustic solution.
4. If there are multiple heat exchangers, arrange them one above the other and have the rich solution enter the tubes of the lowest exchanger and proceed upwards. If possible locate the pressure reducing valve after the heat exchangers to keep the corrosive acid gases in solution. If this is not economically possible it is important to provide a vent tank between the valve and the heat exchangers.
5. All major process equipment should be stress-relieved.
6. Provide adequate baffles for inlet nozzles in all equipment to reduce erosion.
7. Provide a good filter and use it. In small plants cartridge filters are acceptable, while in large plants plate or leaf type filters with provisions for diatomaceous earth precoat are recommended. At least a 10% side stream should be filtered (in the absence of a reclaimer), and the suspended solids concentration of the circulating solution should be no more than 0.01%.
8. A reclaimer should be used if contamination occurs and the concentration of degradation products and/or contaminants exceeds one or two percent depending upon their composition.
9. Sample of the plant solution should be examined regularly to make certain that the free ethanolamine content is adequate, and that the concentration of contaminants is not excessive.
10. The following points should be considered in the operation or design of the still and reboiler. A. Essentially all of the regeneration should be accomplished in the still, not in the reboiler. B. Performance can be checked by comparing the acid gas content of the lean solution entering and leaving the reboiler. C. All the tubes of the reboiler should be fully utilized by making certain that the condensate is removed from the reboiler bundle as rapidly as formed. D. The temperature controller valve should be on the steam inlet, not on the condensate outlet. E. The reboiler bundle should be well immersed at all times, a liquid height of not less than six inches over the top of the bundle is suggested. The heat transfer rate should not be excessively high. F. The removal of tubes to form an open "V" from the center of the tube bundle or an "X" will allow the release of steam generated in the lower portion of the bundle. G. The bundle should be well supported to prevent vibration of the tubes and the tubes should fit tightly in the baffles. H. Teflon inserts are useful in obtaining a tight fit of the tube to the baffle. I. A maximum amine temperature of 250°F is suggested in most cases. J. The lowest possible steam temperature necessary to provide regeneration should be used, preferably 275°F or lower. K. Steam consumption should be at least 1 lb. of steam/gal. of solution circulated. L. A reflux ratio of 1.5 to 2.0 mol water/mol of acid gas removed is also recommended.
11. The regular use of a corrosion test instrument will indicate whether the solution is corrosive so that corrective measures can be taken before significant corrosion occurs.

It is recognized that the foregoing recommendations add to the capital and operating expenses of amine units. Experience indicates, however, that plant upsets, downtime for repairs, and equipment replacements are more costly. Laboratory and plant investigations designed to improve the understanding of corrosion and other operating problems are in progress in many laboratories with the hope that methods will be found for reducing both initial investment and operating costs in amine type treating plants.

### ACKNOWLEDGMENT

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## Operating data for low-temperature recovery units

New data for multicomponent vapor-liquid equilibrium, performance of perforated plate ethane-ethylene splitter, and operation of low-temperature expanders, extends knowledge of operating conditions.

HUMBLE OIL AND REFINING CO. has recently placed in operation a low-temperature fractionation unit which processes catalytic and predominately saturated refinery wet gas streams for the recovery of ethylene and heavier hydrocarbon fractions. The streams processed originate from liquid-vapor separator drums and from the overhead accumulators of fractionation towers throughout the refinery. The combined feed streams to this recovery unit contain  $H_2$ ,  $N_2$ ,  $CO$ ,  $CO_2$ , and  $H_2S$  in addition to the light hydrocarbon compounds which are present in refinery wet gas streams. Most of the hydrocarbon fraction is composed of butanes and lighter compounds; however, hydrocarbon compounds in the gasoline boiling range are present in small amounts.

Since this unit has been placed in

operation, Humble has been able to obtain physical data for light hydrocarbon mixtures which are not readily available in the literature. A portion of these data is presented in this article. Information includes: (1) vapor-liquid equilibrium data, (2) performance data for perforated plate ethane-ethylene splitter, and (3) operating data for a low-temperature expander.

The feed gas streams to the recovery unit are first Girbotol and caustic washed to remove  $H_2S$  and  $CO_2$ . Recovery of the desirable components is then effected by compressing the wet gas streams to above 500 lb./sq.in. gauge and partially condensing the compressed gas in a number of consecutive steps from ambient temperature to  $-170^\circ F$ . The liquid fractions recovered are routed to dis-



Table 1. Analyses of vapor and liquid streams from separator drums.

CONDITIONS	SATURATED STREAMS						CATALYTIC STREAMS					
	Drum no. 1			2			3			4		
	524			520			520			518		
	77			72			92			70		
Pressure, lb./sq. in. gauge												
Temperature, °F												
COMPOSITION, MOL %	Liquid	Vapor	k	Liquid	Vapor	k	Liquid	Vapor	k	Liquid	Vapor	k
Carbon monoxide	..	..	..	..	..	..	..	2.15	..	..	2.15	..
Nitrogen	0.1	..	..	..	0.47	..	..	11.44	..	0.83	13.06	15.5
Hydrogen	0.8	27.08	32.3	..	3.28	..	..	22.44	..	0.80	23.48	26.7
Methane	5.5	43.35	7.9	2.38	21.44	9.0	2.96	21.88	7.4	4.79	22.91	4.8
Ethylene	2.9	3.14	1.07	4.54	11.49	2.5	4.52	9.47	2.1	6.93	9.00	1.30
Ethane	9.7	10.35	1.06	26.28	35.71	1.35	8.29	10.40	1.25	9.86	10.39	1.05
Propylene	1.4	0.67	0.49	5.14	1.80	0.35	26.22	13.55	0.52	28.69	12.26	0.43
Propane	23.3	11.07	0.48	50.88	23.51	0.46	7.36	2.94	0.40	9.39	2.64	0.28
Isobutane	13.8	2.14	0.16	6.89	1.55	0.22	8.96	1.54	0.17	9.12	1.34	0.15
Normal butane	20.5	1.85	0.09	3.89	0.75	0.19	3.06	0.34	0.11	2.41	0.25	0.10
Butylenes	0.4	..	..	..	..	..	23.82	3.49	0.15	20.91	2.59	0.12
Isopentane	13.3	0.25	..	..	..	..	2.81	0.33	0.12	2.23	..	..
Normal pentane	7.5	0.12	..	..	..	..	0.42	0.03	0.07	0.29	..	..
Pentylenes	0.8	..	..	..	..	..	7.15	..	..	3.60	..	..
Heavier	..	..	..	..	..	..	4.43	..	..	..	..	..
	100.00	100.00		100.00	100.00		100.00	100.00		100.00	100.00	

Table 2. Comparison of equilibrium constants.

CONDITIONS:	SATURATED STREAMS											
	DRUM NO. 1; 524 LB./SQ. IN. GAUGE; 77°F			DRUM NO. 2; 520 LB./SQ. IN. GAUGE; 72°F								
	EFFECTIVE			EFFECTIVE			EFFECTIVE			EFFECTIVE		
ESTIMATING METHOD:	ANALYSES	FUGACITY	PRESSURE	CONVERGENCE	CONVERGENCE	CONVERGENCE	ANALYSES	FUGACITY	PRESSURE	CONVERGENCE	CONVERGENCE	CONVERGENCE
COMPOUNDS				1000	5000	1000				1000	5000	1000
Carbon monoxide	..	..	..	..	..	..	..	..	..	..	..	..
Nitrogen	..	..	..	..	..	..	..	..	..	..	..	..
Hydrogen	32.3	..	..	30	30	..	..	..	..	..	..	..
Methane	7.9	4.8	4.8	3.0	5.4	9.0	4.7	4.7	3.0	5.4	..	..
Ethylene	1.07	1.45	1.40	1.50	1.65	2.5	1.37	1.36	1.5	1.55	..	..
Ethane	1.06	1.06	1.02	1.07	1.05	1.35	1.03	1.02	1.1	1.02	..	..
Propylene	0.49	0.47	0.44	0.59	0.45	0.35	0.45	0.44	0.56	0.43	..	..
Propane	0.45	0.44	0.38	0.49	0.36	0.46	0.41	0.41	0.46	0.34	..	..
Isobutane	0.16	0.23	0.20	0.27	0.175	0.22	0.22	0.22	0.25	0.16	..	..
Normal butane	0.09	0.16	0.14	0.22	0.13	0.19	0.15	0.15	0.20	0.12	..	..
Butylenes	..	..	..	..	..	..	..	..	..	..	..	..
Isopentane	..	..	..	..	..	..	..	..	..	..	..	..
Normal pentane	..	..	..	..	..	..	..	..	..	..	..	..
CONDITIONS:	CATALYTIC GAS						MIXTURE					
	DRUM NO. 5; 525 LB./SQ. IN. GAUGE; 68°F			DRUM NO. 6; 464 LB./SQ. IN. GAUGE; -141°F								
	EFFECTIVE			EFFECTIVE			EFFECTIVE			EFFECTIVE		
ESTIMATING METHOD:	ANALYSES	FUGACITY	PRESSURE	CONVERGENCE	CONVERGENCE	CONVERGENCE	MEASURED	FUGACITY	PRESSURE	CONVERGENCE	CONVERGENCE	CONVERGENCE
COMPOUNDS*				1000	5000	1000				1000	5000	1000
Carbon monoxide	..	..	..	..	..	..	..	..	..	..	..	..
Nitrogen	5.5	..	..	16	22	..	..	..	..	4.6	4.6	..
Hydrogen	20	..	..	15	15	..	..	..	..	82	82	..
Methane	2.9	4.5	4.5	3.0	5.4	..	0.97	0.85	0.96	0.90	..	..
Ethylene	1.5	1.35	1.34	1.48	1.55	..	0.10	0.083	0.19	0.13	..	..
Ethane	1.26	0.98	0.98	1.05	1.03	..	0.046	0.031	0.092	0.069	..	..
Propylene	0.40	0.45	0.44	0.54	0.41	..	..	..	..	..	..	..
Propane	0.43	0.40	0.39	0.45	0.33	..	..	..	..	..	..	..
Isobutane	0.15	0.20	0.20	0.25	0.16	..	..	..	..	..	..	..
DEW POINTS, °F	..	..	..	..	..	..	-141	-143	-136	-164	-149	..

\*No data reported for normal butane, butylenes, isopentane, or normal pentane.

## CATALYTIC STREAMS

## MIXED

5			6			7			8			
525 68			464 -141			462 -167			92.5 -215			
LIQUID	VAPOR	k	VAPOR	VAPOR	VAPOR	LIQUID	VAPOR	k	LIQUID	VAPOR	k	
..	..	..	4.73	5.46	..	..	5.38	..	..	..	..	Carbon monoxide
0.53	2.89	5.5	18.99	19.42	5.35	20.15	3.8	Nitrogen	..	..	..	
0.15	3.00	20.0	35.15	37.84	6.90	38.72	5.60	Hydrogen	..	..	..	
5.73	16.40	2.9	35.88	35.52	96.59	35.20	0.96	Methane	..	..	..	
15.82	23.67	1.50	5.12	1.76	49.42	0.55	0.011	Ethylene	..	..	..	
26.77	33.70	1.26	0.13	..	1.74	..	..	Ethane	..	..	..	
41.97	16.82	0.40	..	..	..	..	..	Propylene	..	..	..	
7.91	3.44	0.43	..	..	..	..	..	Propane	..	..	..	
0.55	0.08	0.15	..	..	..	..	..	Isobutane	..	..	..	
0.13	..	..	..	..	..	..	..	Normal butane	..	..	..	
0.44	..	..	..	..	..	..	..	Butylenes	..	..	..	
..	..	..	..	..	..	..	..	Isopentane	..	..	..	
..	..	..	..	..	..	..	..	Normal pentane	..	..	..	
..	..	..	..	..	..	..	..	Pentylenes	..	..	..	
..	..	..	..	..	..	..	..	Heavier	..	..	..	
100.00	100.00		100.00	100.00	100.00	100.00						

## CATALYTIC GAS

DRUM NO. 3; 520 LB./SQ. IN. GAUGE; 92°F					DRUM NO. 4; 518 LB./SQ. IN. GAUGE; 70°F					
EFFECTIVE			CONVERGENCE		EFFECTIVE			CONVERGENCE		
ANALYSES	FUGACITY	PRESSURE	1000	5000	ANALYSES	FUGACITY	PRESSURE	1000	5000	
..	..	..	..	..	..	..	..	..	..	COMPOUNDS
..	..	..	..	..	15.5	..	..	16	22	Carbon monoxide
..	..	..	..	..	26.7	..	..	30	30	Nitrogen
7.4	5.1	5.1	3.1	5.7	4.8	4.7	4.7	3.0	5.4	Hydrogen
2.1	1.57	1.54	1.65	1.7	1.30	1.40	1.33	1.5	1.55	Methane
1.25	1.11	1.07	1.25	1.25	1.05	1.02	0.95	1.05	1.05	Ethylene
0.52	0.57	0.51	0.64	0.52	0.43	0.47	0.40	0.55	0.42	Ethane
0.40	0.51	0.45	0.54	0.42	0.28	0.41	0.35	0.46	0.33	Propylene
0.17	0.27	0.24	0.31	0.21	0.15	0.21	0.17	0.25	0.16	Propane
0.11	0.20	0.17	0.25	0.16	0.10	0.15	0.12	0.20	0.115	Isobutane
0.15	..	..	..	..	0.12	..	..	..	..	Normal butane
0.12	0.11	0.09	0.14	0.07	..	..	..	..	..	Butylenes
0.07	0.08	0.07	0.12	0.06	..	..	..	..	..	Isopentane
					..	..	..	..	..	Normal pentane

## MIXTURE

DRUM NO. 7; 462 LB./SQ. IN. GAUGE; -167°F					DRUM NO. 8; 92.5 LB./SQ. IN. GAUGE; -215°F					COMPOUNDS*
EFFECTIVE			CONVERGENCE		EFFECTIVE			CONVERGENCE		
MEASURED	FUGACITY	PRESSURE	1000	5000	ANALYSES	FUGACITY	PRESSURE	1000	5000	
..	..	..	..	..	..	..	..	..	..	Carbon monoxide
..	..	..	3.2	3.2	3.8	..	..	7.2	7.4	Nitrogen
..	..	..	73	73	5.6	..	..	400	400	Hydrogen
..	0.70	0.55	0.62	0.56	0.96	0.75	0.68	0.72	0.67	Methane
..	0.049	0.035	0.12	0.08	0.011	0.015	0.014	0.052	0.043	Ethylene
..	..	..	..	..	..	..	..	..	..	Ethane
..	..	..	..	..	..	..	..	..	..	Propylene
..	..	..	..	..	..	..	..	..	..	Propane
..	..	..	..	..	..	..	..	..	..	Isobutane
-167	-169	-159	-180	-170	..	..	..	..	..	DEW POINTS, °F

tillation columns for separation into usable streams. Standard and catalytic wet gas streams are processed separately as long as it is economical to do so. The streams are then combined and routed to common demethanization facilities where ethylene and heavier hydrocarbons are recovered. The residue gas stream from the demethanizer tower overhead accumulator is expanded to fuel gas pressure through a two-stage turbine. About six weight percent of the expanded gas is condensed by this operation. The liquid is recovered and recycled to the feed streams entering the unit.

#### Equilibrium data

Little vapor-liquid equilibrium data

are available for the wide range of components usually found in refinery streams. The large number of components in the samples makes the analyses of liquid and vapor fractions tedious and also decreases the accuracy of the results obtained. These difficulties tend to decrease the amount of multicomponent equilibrium data presented in the literature. As a result, most correlations for estimating vapor-liquid equilibrium constants for various compounds are based on binary data. The question always exists as to how well these correlations predict equilibrium constants for mixtures containing a large number of components.

Humble's unit contains a number of drums where liquid and vapor

streams are separated. Analyses for the streams of eight of these drums are presented. The usual difficulties in obtaining accurate analyses for streams containing large numbers of compounds were experienced. In addition to these difficulties, errors could be realized by improper sampling techniques and by nonequilibrium conditions in the unit.

In an effort to minimize possible errors, triplicate samples of each stream were taken over a period of three hours. Rough analyses were run on all three samples. If all of the rough analyses for any one stream appeared to be the same, then detailed analyses were performed on two of the samples. If discrepancies existed, all three samples were analyzed in





detail. Mass spectrographic and gas chromatographic analyses were made on each sample. In combining these results to form the analyses for the samples, particular emphasis was given to the type of analysis which usually gave better accuracy for the component under consideration. In some cases the streams were further processed in the recovery unit and separated into smaller streams. These operations tended to concentrate the trace compounds. Where possible, analyses were improved by material balances around subsequent pieces of equipment.

The analyses obtained have been summarized in Table 1. Excellent precision in the analyses was obtained on all samples except those for the

two liquid streams of the saturated gas section. In general, component analyses agreed with each other to within two percent or less (based on the amount of component present). In a few cases deviations were as much as five percent; also, a few deviations were as high as ten percent in cases where components were present in concentrations of less than one percent. Reasonable agreements were also obtained in the material balances around the knock-out drums.

Equilibrium constants calculated from the analyses of the vapor and liquid streams are compared in Table 2 with equilibrium constants estimated by the following: fugacity of the individual hydrocarbons, the ef-

fective pressure method (1) for mixtures of light hydrocarbon compounds and other gases, and convergence pressure charts (2). It was impractical to analyze the liquid streams from two knock-out drums. In these cases, dew points for the vapor streams were calculated and compared with the temperatures measured.

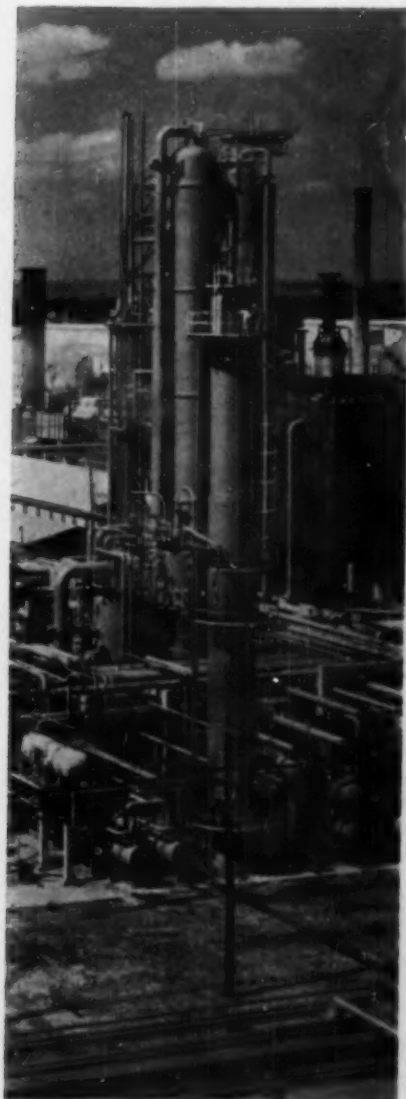
#### Data analysis

In general, the equilibrium constants determined from the plant analyses were in fair agreement with each other. In some cases the values for the equilibrium constants calculated for propylene were lower than similar values calculated for propane. This indicates that small errors exist in the analyses of one or both of these

Table 3. Ethylene-ethane splitter operating data.

	TEST 1	TEST 2*	OVER-ALL AVERAGE
Splitter design:			
Number of trays	53	53	53
Vapor overhead, tray number	1	1	1
Feed inlet, tray number	32	32	32
Reflux inlet, tray number	1	1	1
Splitter temperature, °F:			
Overhead	-75.0	-74.9	-75.0
Tray 5	-75.8	-74.4	-74.6
Tray 13	-68.9	-67.5	-68.2
Tray 16	-60.5	-59.4	-60.0
Tray 25	-53.0	-53.0	-53.0
Tray 29	-52.0	-52.4	-52.2
Feed	-53.2	-53.4	-53.3
Tray 33	-51.6	-51.8	-51.7
Tray 42	-39.0	-39.0	-39.0
Bottoms	-38.0	-38.0	-38.0
Splitter pressure, lb./sq.in.gauge:			
Overhead	98	97	97.5
Feed	100	99	99.5
Bottoms	102	101	101.5
Flow rates, mols/100 mols feed:			
Overhead vapor	275	281	278
Overhead product	50	51	50
Liquid reflux	225	230	228
Bottoms product	50	49	50
Reboiler duty, 1000 B.t.u./hr.	1,216	1,224	1,220
Compositions, mol % ethylene:			
Overhead product	99.31	99.11	99.21
Feed	50.28	50.74	50.51
Bottoms vapor	0.03	0.01	0.02
Splitter vapor, Tray 1	99.27	99.05	99.17
Splitter vapor, Tray 8	92.99	92.32	92.66
Splitter vapor, Tray 33	28.91	30.56	29.74
Splitter vapor, Tray 41	1.38	1.78	1.58
Plate efficiencies, %:			
Entire tower	88.9	92.5	90.7
Top 8 trays	104.2	95.8	100.0
Top 33 trays	97.0	92.9	95.0
Top 41 trays	99.6	95.1	92.4
Top through feed tray	96.5	93.4	94.9

\*Test 2 seemed to be the better run.



Low temperature recovery unit at Humble Oil & Refining Company, Baytown, Texas.

compounds. At ambient temperature, the equilibrium constants calculated for methane were usually higher than those estimated from the previously mentioned correlations. The equilibrium constant calculated for ethylene at  $-215^{\circ}\text{F}$  was considerably lower than those estimated.

In most cases, only trace amounts of hydrogen were present in the liquid streams and small errors in the analyses would make large errors in the calculated values. One of the constants calculated for hydrogen is of interest, however. At  $-215^{\circ}\text{F}$  the value obtained was only about one one-hundredth of the expected value. Sufficient concentrations of hydrogen were present in the liquid samples to make the calculated values accurate unless significant errors exist in the analyses. It is unfortunate that liquid samples could not be taken on the other two low-temperature drums to check this discrepancy. It is planned to add connections so these streams can be sampled in the near future.

The dew point temperatures calculated for the gas streams leaving Drums 6 and 7 using the equilibrium values estimated from fugacity correlations for light hydrocarbon compounds were very close to the actual temperatures measured. Usually, the use of such equilibrium constants for mixtures of hydrocarbons and other compounds results in the estimated temperatures being quite different from the true value. It is felt that the agreement in these cases may have been a coincidence. It is also surprising that the equilibrium constant estimated for ethylene at  $-215^{\circ}\text{F}$  from the fugacity and effective pressure methods was significantly closer to the measured value than those estimated from the convergence pressure charts.

No one method of estimating equilibrium values consistently gave values close to those calculated from the analyses. If one knew the proper convergence pressure to use for a given mixture, this method would probably be superior to other short-cut methods. In general, the equilibrium charts prepared for high convergence pressure mixtures should be used for mixtures containing significant quantities of hydrogen and similar gases. There is some indication that charts for different convergence pressures should be used for the various compounds of a mixture. Considerably more data are needed before a rule-of-thumb method can be developed for use of these charts.

#### Process equipment

Considerable interest has been shown in the last few years concern-

**Table 4. Operating data of expander on demethanizer**

#### OPERATING CONDITIONS

Demethanizer overhead temp., $^{\circ}\text{F}$	-167
Demethanizer overhead pressure, lb./sq. in. gauge	462
Expander inlet temp., $^{\circ}\text{F}$	-174
Expander inlet pressure, lb./sq. in. gauge	324
Expander outlet temp., $^{\circ}\text{F}$	-215
Expander outlet pressure, lb./sq. in. gauge	93
Expander liquid, wt. %	3.74

#### STREAM ANALYSES, MOL %:

COM- PONENT	EX- PANDER INLET FEED	EX- PANDER LIQUID	DIS- CHARGE VAPOR
CO	5.28	....	5.38
N <sub>2</sub>	19.84	5.36	20.15
H <sub>2</sub>	37.83	6.90	38.72
CH <sub>4</sub>	35.31	36.58	35.20
C <sub>2</sub> H <sub>6</sub>	1.70	49.42	0.55
C <sub>3</sub> H <sub>8</sub>	0.04	1.74	....
	100.00	100.00	100.00

ing fractionation columns containing perforated plates. The data for our ethane-ethylene splitter are presented to extend the range of operating conditions reported in the literature for this type of tower. Operating temperatures for the splitter column range from  $-40^{\circ}\text{F}$  to  $-80^{\circ}\text{F}$ . Two test runs were conducted and data from these tests are summarized in Table 3.

Since calculated plate efficiencies would have been quite sensitive to small errors in the analyses at the normal operating conditions for this tower, the purity of the overhead stream was decreased to 99.2 mol % ethylene during the test period. This resulted in the feed plate of the tower

being about eight plates lower than optimum. This situation was taken into account in estimating the plate efficiencies. Samples were taken at intermediate points in the tower in order that plate efficiencies for the various sections could be calculated. In those sections where ethane and ethylene concentrations were such that accurate analyses could be made, the plate efficiencies were between 93% and 104%.

Centrifugal expanders are being installed on low-temperature recovery units to obtain economical refrigeration at temperature levels below that obtainable with ethylene refrigeration. A two-stage centrifugal expander was chosen for this operation. Saturated demethanizer overhead vapors are charged to the expander, and the exit stream contains about six weight percent liquid. Typical operating conditions for the expander are presented in Table 4.

#### Conclusions

The main conclusion which can be drawn from the equilibrium data presented is that considerably more data are needed for mixtures containing large numbers of compounds. The data presented have shown some interesting discrepancies between predicted and calculated equilibrium constants for several compounds. Others are encouraged to publish their operating data so that it can be determined whether errors exist in predicting vapor-liquid equilibrium constants for multicomponent mixtures or whether a bias error exists in our data.

Plate efficiencies of 90% to 95% should be realized from perforated plate fractionation columns processing ethane-ethylene mixtures at low temperatures and pressures.

Centrifugal expanders are now an economical method of obtaining low-temperature refrigeration on process units.

#### ACKNOWLEDGMENT

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## New route to acrylonitrile

Simultaneous research, development, and design highlight the rapid commercialization of this new process.

THE STANDARD OIL CO. OF OHIO brought a large plant on stream in mid-1960 at Lima, Ohio, to produce acrylonitrile by a new route based on a single step, direct conversion of propylene, ammonia, and air. This new process appears likely to become a major factor in future production of acrylonitrile because of the universal availability of the raw materials.

Interest in acrylonitrile stems from its great utility and versatility. This material appears destined to become one of the large volume organic chemicals manufactured on a world-wide basis. It is capable of considerable chemical activity because of its two chemically reactive groups, the olefinic double bond and the nitrile

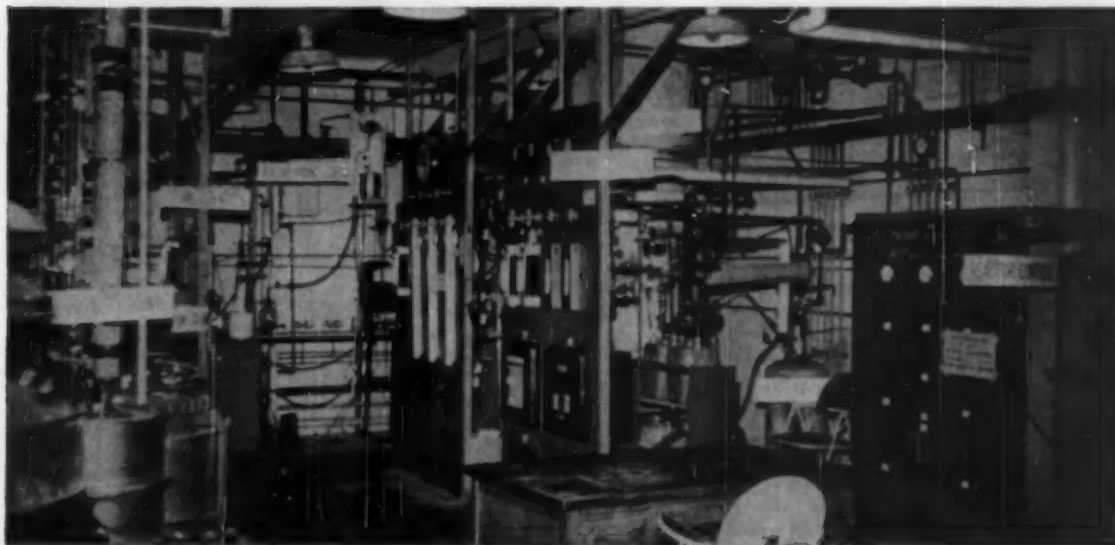
group. It exhibits the reactions characteristic of the regular double bond such as polymerization and the characteristic reactions of the nitrile group such as hydrolysis. Also possible are the special reactions associated with conjugated multiple bonds such as addition or condensation.

Production of acrylonitrile in the U. S. has grown very rapidly from almost nothing to 200 million pounds annually in less than ten years. There is an anticipated demand for 400 million pounds in the U. S. by 1965. A similar growth trend outside the U. S. is also estimated.

The present use pattern is as follows:

Use	Million Pounds	
	1958	1960
Acrylic Fibers	125	190
Nitrile Rubber	28	48
Plastics	10	20
Others	15	20
Total	178	278

So far, applications are completely dominated by acrylic fibers which are steadily increasing in types and number. However, the general long-range prospect of lower cost acrylonitrile might be expected to have a greater growth impact on the nitrile rubbers and plastics than the acrylic fibers. Particularly in the plastics area, the use of acrylonitrile has apparently been held back by relatively high



Pilot plant equipment shows reactor in background, recovery units at left, and associated auxiliary equipment.



prices compared with other monomers. With acrylonitrile already available at twenty-three cents per pound, it represents, by far, the lowest cost acrylic monomer available.

### Present manufacturing processes

Predominantly, acrylonitrile has been made commercially by two processes. One of the earliest processes used ethylene cyanohydrin made by combination of ethylene oxide with HCN. The dehydration to acrylonitrile occurs readily and cleanly.

In more recent years, the trend has gone to combination of HCN and  $C_2H_2$ . This reaction is generally conducted in the liquid phase with copper salts as catalyst.

One feature of this route is the production of by-product acetylenic compound impurities such as cyanobutadiene and divinylacetylene. Both of these are difficult to separate from the acrylonitrile and must be removed down to the p.p.m. concentration range to avoid trouble in the polymerization of the acrylonitrile monomer.

Both of the previous routes have reached a high level of efficiency and an advanced state of engineering. While the acetylene route is not as simple and clean as the ethylene cyanohydrin route, it appears to have been winning the economic race, particularly for the larger size plants now being employed.

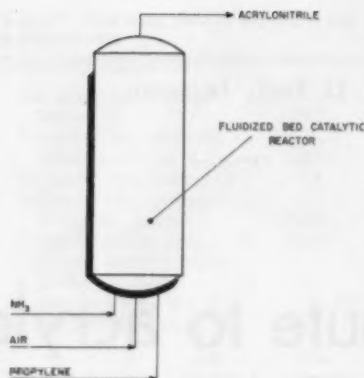
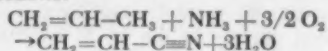


Figure 1. New Sohio route to acrylonitrile from propylene,  $NH_3$ , and air.

A recent new candidate which has received considerable publicity is the Knapsack-Griesheim process originating in Germany. It substitutes acetaldehyde for ethylene oxide or  $C_2H_2$  and goes through lactonitrile as the intermediate followed by dehydration to acrylonitrile. This process is still limited to the pilot plant and would appear to have no raw material advantage over acetylene.

### The Sohio-acrylonitrile process

The chemistry of the new route is as follows:



The reaction is highly selective, giving good yields of acrylonitrile along with commercially recoverable amounts of the valuable by-products, acetonitrile and hydrogen cyanide.

As indicated in Figure 1, the reaction flow diagram is quite simple. It consists of a catalytic, vapor-phase, one-step conversion operating at moderate temperatures (below  $500^\circ C$ ), ordinary pressures (below three atmospheres), and residence times of a few seconds.

Refinery propylene and conventional fertilizer grade anhydrous ammonia along with air are the only raw materials. Propylene concentration is not critical, with 40-90% propylene acceptable as reactor feed. Substantial amounts of lower molecular weight hydrocarbons can be tolerated in the feed streams. In some cases economics may warrant a preconcentration of the propylene, but this is not dictated by process requirements. All of the raw materials cost less and are more abundant on a world-wide basis than the previously used raw materials: HCN, ethylene oxide, and/or  $C_2H_2$ . Not only does the process substitute the lower cost  $NH_3$  for HCN, but it actually produces commercially recoverable by-product quantities of the latter.

The other major by-product is acetonitrile, which previously sold at such a high price as to preclude volume



Figure 2. Equipment used in initial research for Sohio's new process for producing acrylonitrile with reactors shown at right.

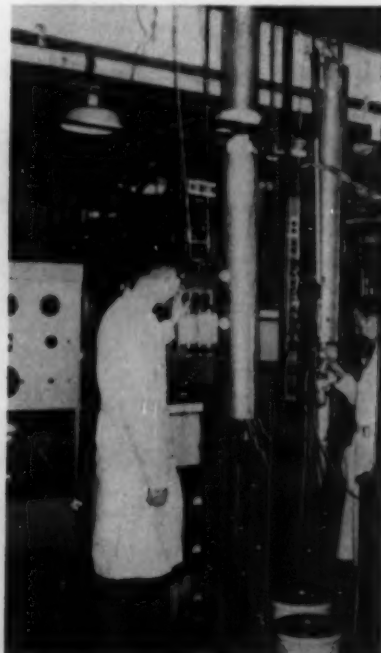


Figure 4. Reactor operating information was obtained in the above equipment.



usage. Acetonitrile is a powerful resin solvent and has some other unique features associated with the extremely high polarity of the cyano group.

**Catalyst.** The catalyst is used in a fixed fluidized bed reactor and requires ruggedness, both physical and thermal, and proper particle shape and size distribution to fluidize well. The precise physical and chemical structure to produce the desired reaction with high efficiency must also be maintained over long operating periods.

The catalyst depends for its activity on a high concentration of active ingredients rather than a trace constituent. Consequently, it is not readily affected with trace contaminants.

**Product recovery.** Hydrocarbon oxidation processes are often plagued with extremely complex product recovery and purification systems. Because of the relatively simple mixture obtained in this case, recovery and purification steps are comparatively simple.

Reactor effluent is treated to separate fixed gases and unreacted hydrocarbon which pass to a stack or to recycle recovery equipment as the particular feed values dictate. The acrylonitrile separation and purification units utilize conventional distillation techniques. By-product acetonitrile is similarly recovered and purified. A high concentration HCN stream can also be reclaimed for commercial processing if desired.

Acrylonitrile sells commercially as an extremely high purity organic chemical. The product quality from this process is exceptionally high with none of the troublesome acetylenic impurities present.

### Research and development

The process was extensively tested by operation of a pilot plant unit for several months at the Sohio Research Center in Cleveland. The product from this unit was fiber grade and met major U.S. consumer specifications. Substantial quantities were polymerized, spun into fiber, dyed, and aged with complete acceptance.

Some of the special aspects of the research and development program may be of interest. The initial research work was conducted in small units of the type shown in Figure 2. Small steel tubular reactors with a catalyst charge of approximately 100 c.c. were employed. Vapor chromatography was used extensively as the major analytical tool.

The reaction studies were supported with special product recovery and separation studies. Multiplate glass

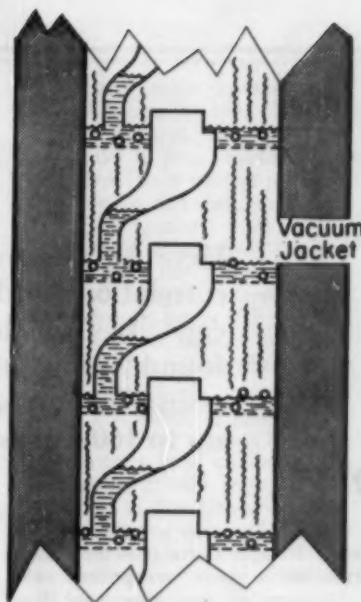


Figure 3. Section of Oldershaw column.

Oldershaw distillation columns with an internal design shown in Figure 3 were used to obtain design data. This column resembles a miniature glass sieve tray complete with downcomers. One- and two-inch diameter units of appropriate plateage were used. Correlation of work done in this equipment with actual plant operation has been excellent in spite of the tremendous scale-up factors.

The second step in the reactor scale-up was conducted in equipment of the type shown in Figure 4, called "Advancement" units. They had an internal diameter of about three inches and employed one to two liters of catalyst charge. Much of the basic plant reactor design and operating information came from units of this size with little or no modification ensuing from the subsequent larger scale pilot plant operation.

### Pilot plant evaluation

The pilot unit operation was not aimed at securing detailed plant design data but predominantly to give a firm evaluation of catalyst life and to supply market development samples.

The pilot unit chosen was an 18-in. I.D. reactor with a catalyst charge of several hundred pounds. The introductory photo shows the reactor and auxiliary equipment. The recovery equipment was of the Oldershaw type made predominantly of glass units in the four- and six-inch diameter size range.

It may be of special interest to note that certain phases of the research work, the process advancement work, the pilot operation, and the detailed plant design were all conducted simultaneously. This type of simultaneous operation can greatly compress the time required to get an interesting process to plant stage. It creates a certain amount of discomfort and occasional back-tracking, but over-all progress can be speedily made if all groups involved are in close proximity and daily contact.

It also brings to bear at an early stage the tremendous know-how available from the contract firms and can save substantial amounts of money in eliminating pilot scale work not needed for actual plant design.

The detailed plant design shows it will have a low electrical load, a relatively small fresh water requirement, will be self-sufficient in steam, and will produce no unusual water effluent. Detailed economic studies indicate that for essentially all foreseeable sets of economic conditions and plant sizes, the Sohio process compares favorably with conventional routes in respect to investment, raw materials, operating costs, and product quality. It appears that small plants can be fully competitive with the previous larger facilities which had to be integrated with HCN,  $C_2H_2$ , or ethylene oxide production. Plants do not have to be at the raw material site, since both propylene and anhydrous ammonia are readily transported. Plant construction materials are conventional and all operations are near atmospheric pressure except for steam generation.

### Commercial aspects worldwide

Sohio has decided to commercialize this process abroad and an active exploitation program is underway on a world-wide basis. It appears that many foreign countries are eager to enter or expand acrylic fiber manufacture. The new raw material picture supplied by this process enables operation at many sites where production from  $C_2H_2$  and HCN would be impossible or uneconomic.

### ACKNOWLEDGMENT

Permission of the Standard Oil Co. of Ohio to present this paper is gratefully acknowledged as well as the many contributions of the authors' co-workers. For outstanding contribution to the development of this process, particular mention is due to G. G. Cross of Sohio Chemical Co.

# Cryogenic impurity adsorption from hydrogen

THE IMPURITIES THAT MUST be removed in the production of liquid hydrogen vary in type and quantity depending on the source of the raw feed gas. Whether this gas is derived as a product of electrolysis or from some petroleum process, one or more of the low boiling gases:  $N_2$ ,  $O_2$ , A, CO, or  $CH_4$  will be encountered in quantities ranging from a few parts per million to a few percent. With the exception of  $O_2$ , the accepted method for removing these impurities in concentrations up to several thousand parts per million is low-temperature, high-pressure adsorption just prior to liquefaction. The operating pressure of the adsorber as determined by the position of this unit in the cycle can be as high as 140 atm.; the operating temperature will normally be in the range of the boiling point of liquid nitrogen.

For sound design calculations it is necessary to know adsorptive capacities for these impurities for the adsorbent and temperature employed and what effect the presence of the carrier gas has on this capacity. The purpose of this article, then, is to present for one temperature: a comparison of pure component adsorption isotherms for the more predominant impurities ( $N_2$ , CO, and  $CH_4$ ), the effect of total pressure on the adsorption of a given impurity from hydrogen gas, and from these an empirical correlation enabling one to predict the variation in adsorptive capacity with impurity level for any selected operating pressure up to 100 atm.

An important factor in the critical evaluation of adsorption data is the variation which can exist in a given grade of adsorbent. The source, the mode of preparation, and reactivation procedures all contribute to this vari-

ation. In order to compare the adsorption of a pure component with adsorption of this component from hydrogen carrier gas, the same adsorbent sample and reactivation procedure must be used in both pure component and binary experiments.

A high capacity grade of silica gel (identical to that currently in use in the purifier units of the National Bureau of Standards hydrogen liquefier) and a temperature of 76°K were chosen for this investigation to allow comparison of experimental and predicted capacities with observed purifier unit capacities for nitrogen.

## Pure component isotherms

The experimental apparatus used to determine the pure component isotherms at 76°K, Figure 1, consisted

of the adsorption cell, a source of adsorbate, a manometer to determine the equilibrium adsorption pressure, and a wet-test meter to measure the quantity of gas desorbed from the silica gel at each pressure. A low vapor pressure oil was used as the manometer fluid to measure the lower adsorptive pressures. This particular oil provided a reading, for an equivalent pressure, approximately 14 times that of the mercury manometer used to measure the highest adsorptive pressures. The capacities determined by metering the gas desorbed from the gel (in this case at 250°F with appropriate free volume corrections) is not expected to differ significantly from those determined by measuring the volume adsorbed.

The adsorption cell is stainless steel

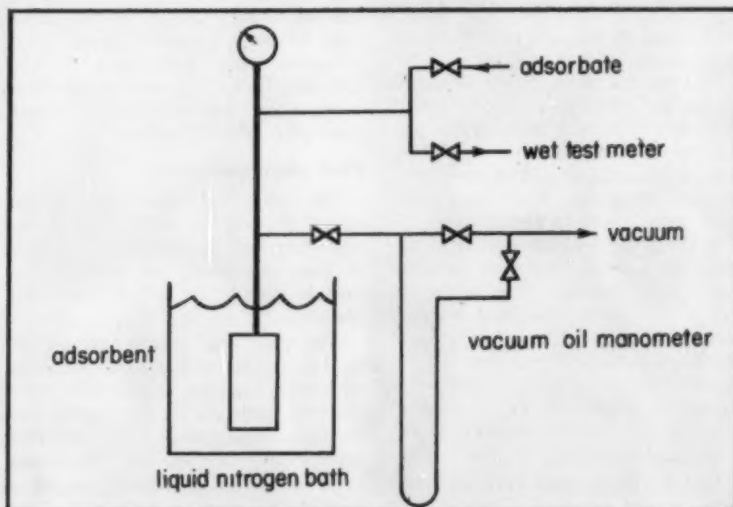


Figure 1. Pure component experimental adsorption apparatus.

approximately 1/8-in. diam. and 6-in. long, 20.71g. of silica gel with a particle size of 6-10 mesh, is held in place by wire screens mounted in brass rings. From helium free-volume measurements the actual volume occupied by the gel was found to be 10.3ml. in a total cell assembly volume of 54.4ml. leaving a free volume of 44.1 ml<sup>3</sup>.

Since N<sub>2</sub> and CO are similar in physical properties, emphasis in this work has been placed on N<sub>2</sub> and CH<sub>4</sub>, the N<sub>2</sub> data providing the basis for determining the surface area of the adsorbent, evaluating the CH<sub>4</sub> isotherm, and plotting a CO isotherm with limited data. Though the methods employed in evaluating the pure component isotherms are well known, it is worth while to briefly outline the equations that have been employed and the results of the evaluation.

The B. E. T.<sup>2</sup> equations (1) for multilayer adsorption are given as:

$$\frac{p}{v(p_0 - p)} = \frac{1}{v_m c} + \frac{(c-1)}{v_m c} \cdot \frac{p}{p_0} \quad (1)$$

and

$$v = \frac{v_m c X}{(1-X)} \quad (2)$$

$$\times \left[ \frac{1 - (N+1)X^N + NX^{(N+1)}}{1 + (c-1)X - cX^{(N+1)}} \right]$$

where

$$c = e^{(E_1 - E_L)/RT} \text{ (approx.)}$$

$E_1, E_L$  = the heat of adsorption of the first layer and the heat of liquefaction of the adsorbate resp., cal./g-mole

$p$  = equilibrium adsorption pressure, mm Hg

<sup>2</sup>B.E.T.: Brunauer, Emmett and Teller

$p_0$  = normal vapor pressure of the adsorbate at the adsorption temperature, mm Hg

$X$  = equal to  $p/p_0$ , commonly referred to as relative pressure

$v$  = volume adsorbed, cu.cm. at STP/g. at  $p$

$v_m$  = volume of adsorbate required to cover one gram of adsorbent with a monomolecular layer, cu.cm. at STP

$N$  = maximum number of layers that can be adsorbed up to  $p = p_0$ .

Equation 1 is based on infinite layer adsorption at  $p = p_0$ , whereas Equation 2 provides for a finite number of adsorbed layers at the high relative pressures.  $N$  in Equation 2 is determined by trial and error to fit experiment.

The surface area of the adsorbent can be calculated from isotherm data using:

$$S = (v_m/22,415) AN_a \quad (3)$$

where:  $S$  = the surface area of the adsorbent, sq. cm./g. of adsorbent.

$A$  = area covered by one molecule, sq. cm.

$N_a$  = Avogadro's number

It is only necessary to obtain values for  $v_m$  and  $A$ . Assuming that the adsorbed molecules have the same packing on the surface as the condensed phase of the adsorbate, Brunauer (2) obtained Equation 4 for an area covered by one molecule in the plane of closest packing.

$$A = 4(0.866) \left[ \frac{M}{4\sqrt{2} N_a d} \right]^{2/3} \quad (4)$$

where:  $M$  = molecular weight of adsorbate

$d$  = density of the condensed phase

$M/d$  = molal volume

The density of either liquid or solid can be used in this expression depending on adsorbate and temperature. Combining Equations 3 and 4 we obtain:

$$S = (4.11 \times 10^3) v_m (M/d)^{2/3} \quad (5)$$

which was used with the experimental N<sub>2</sub> data to calculate the silica gel surface area.

The pure component obtained is listed in Table 1, where  $p$  is the equilibrium adsorption pressure in mm. of Hg. and  $v$  is adsorptive capacity for the subject gas in cu. cm. (STP)/g. of adsorbent.

In plotting  $\frac{p}{v(p_0 - p)}$  vs. the relative pressure, straight lines should be obtained for relative pressures between 0.05 and 0.15, with intercepts equal

to  $\frac{1}{v_m c}$  and slopes of  $\frac{(c-1)}{v_m c}$ , Figure

2. As expected, the experimental data deviates from Equation 1 in such a manner as to indicate more actual adsorption at the low relative pressures, where the most active sites are involved, and less at the higher relative pressures, where the adsorbent may have a limit of a finite number of layers. Data for both N<sub>2</sub> and CH<sub>4</sub> fit Equation 2 well for  $N = 2$  at the higher relative pressures.

One would also expect from the molal volumes that  $v_m$  for N<sub>2</sub>, CO, and CH<sub>4</sub> would be approximately the same if there were no anomalies in the data. The values derived from the pure component isotherms, using the preceding equations and B.E.T. plots, are listed in Table 2.

The important points to be noted from Table 1 are that: the spread in values of  $v_m$  is only 5%; the surface

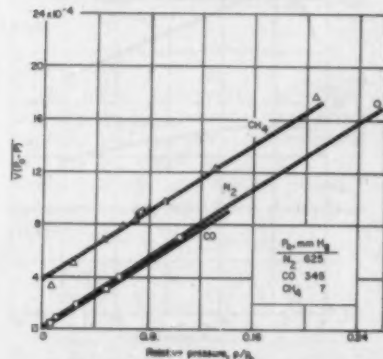


Figure 2. B.E.T. plot of 76°K silica gel isotherms.

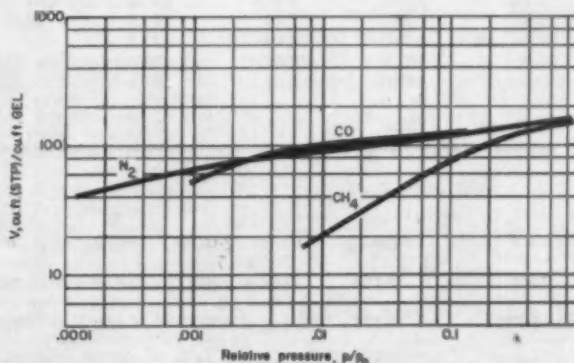


Figure 3. Adsorption isotherms for silica gel at 76°K.



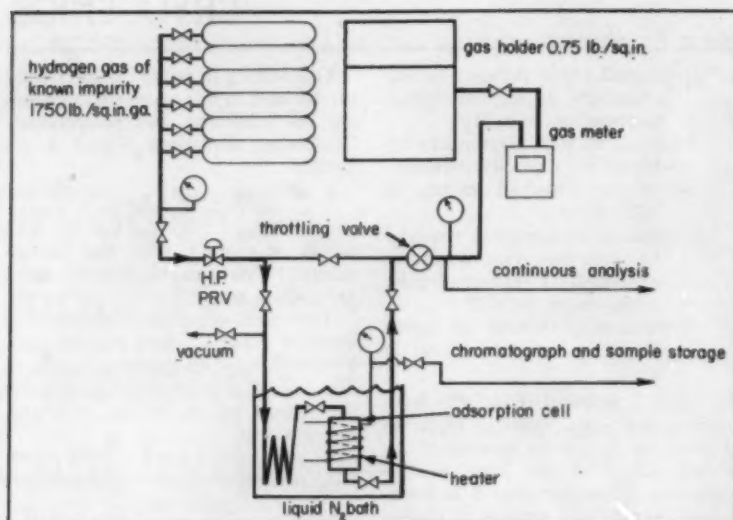


Figure 4. Schematic of impurity adsorption apparatus.

areas calculated from the two CO points and the more extensive  $N_2$  data differ by less than 2%; the calculated density of the condensed  $CH_4$  phase is approximately what one might expect by extrapolation of density data available in the literature (3, 4); and the relative values of  $\Delta E$  for  $N_2$  and CO are of the magnitude observed by others (1).

The CO isotherm can be plotted between 0.15p. and 0.001p. with reasonable confidence since the point at 0.0062p. fits the B.E.T. equation very well and the intercept is so near zero. The three resulting isotherms are plotted in Figure 3. It should be

noted that the B.E.T. fit of the experimental data of  $CH_4$ , for example, verifies the comparative shape of the resulting isotherm, but not necessarily the exact magnitude of capacity.

Adsorptive capacities most commonly are expressed in weight or STP volume of adsorbate per unit weight of adsorbent. For sake of convenience of the designer, the capacities found in this investigation have been converted from cu.cm. (STP)/g. to cu. ft. (STP)/cu. ft. using 45 lb./cu. ft. as the average dry "bulk density" of this particular silica gel. The values can be recovered in units of cu.cm. (STP)/g.

$N_2$		Table 1 $CH_4$		CO	
P	v	P	v	P	v
0.072	57.3	0.049	21.6		
0.094	60.0	0.072	35.1		
0.275	77.8	0.167	48.4		
0.579	88.5	0.325	70.8		
1.01	95.0	0.427	82.4		
2.21	106.0	0.492	90.4	2.14	129.4
3.23	112.0	0.651	105.5		
7.16	124.6	0.918	123.5		
16.8	140.0	1.45	146.5	16.65	160.7
37.2	156.0	2.14	171.1		
65.8	167.8	3.51	198.0		
159.0	197.0	5.21	203.6		
293.5	214.0				
518.0	222.0				

Isotherm	Table 2 M		$S$ $M_2/g.$	c	$E_1-E_L$ cal./g.-mole
	$v_m$ cu.-cm./g.	$\frac{d}{d}$ cu.-cm./g.-mole			
$N_2$ , 76°K	153	( $d_L = 0.812$ ) 34.5	668	362	890
CO, 76°K	157	( $d_L = 0.818$ ) 34.3	680	797	1008
$CH_4$ , 76°K	150	( $d = 0.45$ ) <sup>*</sup> 35.6	..	16.7	425

\* Calculated from Equation 5 using  $S = 668M^2/g.$

simply by dividing by 0.72.

### Impurity adsorption at 76°K

With reliable isotherms for the pure components available, it is necessary to know how these can be utilized in the practical case where one of the components appears as an impurity in hydrogen gas. Ideally, the relative pressure calculated from Dalton's Law of partial pressures would indicate that for a given impurity level the adsorptive capacity would always increase with total system pressure if only impurity were adsorbed.

To determine how the actual case deviates from the ideal, capacities of silica gel were determined for specific concentrations of  $N_2$  in  $H_2$  and  $CH_4$  in  $H_2$  from 5 to 100 atm.

The experimental apparatus is shown schematically in Figure 4. The high pressure feed storage consists of 30 individually-valved tubes with a capacity of approximately 1000 STP cu. ft., each. The desired impurity levels were attained by injecting the desired amount of  $CH_4$  (or  $N_2$ ) into the low pressure side of a liquefier plant compressor, pumping purified hydrogen gas, and filling the selected tubes to 1750 lb./sq. in. ga. Resulting mixtures were analyzed with a mass spectrometer to check the impurity concentration and to ascertain that no other impurity was present. Eight tubes at 450 p.p.m. of  $CH_4$  and seven tubes of 915 p.p.m. of  $N_2$  were prepared by this method. The remaining fifteen tubes contained pure hydrogen gas.

The adsorption cell (with adsorbent) is the same one that was used in the pure component experiments. The operating pressure of the cell was set by a high pressure PRV in the feed line, and the flow was controlled

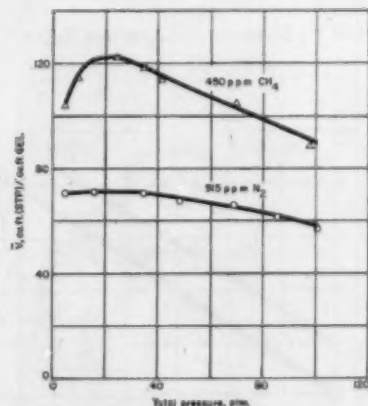


Figure 5. Effect of solvent gas pressure on adsorptive capacity.



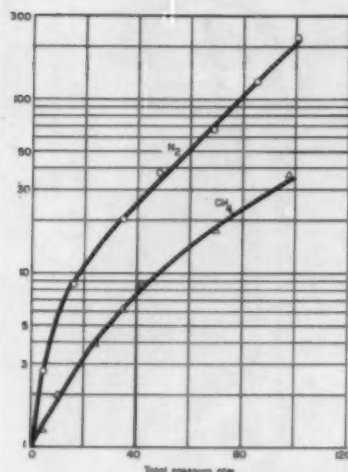


Figure 6. Adsorption enhancement factors for  $\text{CH}_4$  and  $\text{N}_2$  at  $76^\circ\text{K}$ .

at 0.8 SCFM with the throttling valve located in the discharge line. With the by-pass and the inlet to the cell opened initially, the desired operating conditions were set and an impurity trace was obtained on the continuous thermal conductivity analyzer. The by-pass was then closed and the cell discharge opened to allow the flow to pass through the cell and the analyzer to return to zero.

The adsorption cell was isolated when the quantity of impurity in the cell discharge reached the same level as the feed gas. The gas mixture obtained from the cell in bleed-down, warm-up, and desorption was collected in a sample gas holder and analyzed in a chromatograph with an occasional check by mass spectrometer analysis. In calculating capacities, it was assumed that the gas remaining in the free volume of the cell was pure  $\text{CH}_4$  (or  $\text{N}_2$ ).

The results shown in Figure 5 deviate radically from the ideal; in fact for both  $\text{CH}_4$  and  $\text{N}_2$  the capacity decreases for total pressures above 30 atm.

### Correlation

The curve representing adsorptive capacity vs. total pressure for a given impurity level and adsorption temperature can be related to the "pure" impurity isotherm at the same capacity by a dimensionless factor defined as follows:

$$\phi = \frac{Y_2 \pi}{p_0} = \frac{Y_2 \pi}{p} \quad (6)$$

$Y_2$  = impurity level, by vol.

$\pi$  = total pressure, atm.  
 $p$  = equilibrium adsorption pressure, atm.  
 $p_0$  = normal vapor pressure of the pure impurity, atm., at the adsorption temperature

For example, at  $76^\circ\text{K}$ , 60 atm. total pressure, and  $Y_2 = 915$  p.p.m.  $\text{N}_2$ , we find that silica gel has a capacity of 66 cu. ft.  $\text{N}_2$  (STP)/cu. ft. of gel. The relative pressure on the pure gas isotherm corresponding to this capacity is  $1.3 \times 10^{-3}$ , and the normal vapor pressure of  $\text{N}_2$  at  $76^\circ\text{K}$  is 0.82 atm. Then

$$\phi = \frac{(9.15 \times 10^{-4}) (60 \text{ atm.})}{(1.3 \times 10^{-3}) (0.82 \text{ atm.})} = 52$$

Because of the similarity in appearance between this factor and the Dokoupil "Enhancement Factor" (5),  $\phi$  will be referred to as the "adsorption enhancement factor" to denote a difference in definition.

The "adsorption enhancement factors" for  $\text{N}_2$  and  $\text{CH}_4$  at  $76^\circ\text{K}$  vs. total pressure are plotted in Figure 6. One can easily see that assuming a Dalton Law relationship could result in rather large errors. For example, using  $\phi = 1$  for 1000 p.p.m.  $\text{N}_2$  in  $\text{H}_2$  at 100 atm. would result in an error in relative pressure in excess of two orders of magnitude and in capacity of about 70%.

If one assumes that the "adsorption enhancement factor" is a function of temperature and total pressure only, it is possible to calculate the change in capacity with impurity level for any selected operating pressure within the applicability of the experiments. The "impurity isotherms" calculated for  $\text{CH}_4$  in  $\text{H}_2$  and  $\text{N}_2$  in  $\text{H}_2$  at 60 atm. are compared in Figure 7. The experimental points shown are the results of NBS plant-scale tests for  $\text{N}_2$  in  $\text{H}_2$  at the same adsorption pressure and temperature, and complete saturation of the purifier (6). The dotted vertical line on the

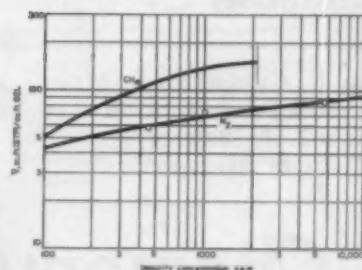


Figure 7. Impurity isotherms for silica gel at  $76^\circ\text{K}$  under 60 atm.  $\text{H}_2$ .

$\text{CH}_4$  curve represents the saturation concentration in  $\text{H}_2$  at 60 atm. total pressure.

### Summary

A nice feature of the "adsorption enhancement factor" correlation is that its utility is not limited to the silica gel adsorbent from which it was derived. If pure gas isotherms for either  $\text{CH}_4$  or  $\text{N}_2$  are available for other adsorbents their factors can be applied in the manner just described. Reasonable capacities can be calculated even when only surface areas are available (1). The obvious disadvantage is that of temperature limitation. In addition, prediction of effective adsorber capacities in plant applications involves considerations for geometry of the column, duration of the impurity front, fluctuations in impurity level, and adsorptive interference between impurities. Nevertheless an understanding of the enhancement effect makes this prediction a much easier task.

### ACKNOWLEDGEMENTS

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# Chemonuclear reactor

Preliminary studies indicate that a one megawatt reactor is a promising source of ionizing radiation for industrial chemical reactions.

THE AEC HAS STIPULATED that the broad technological goals in regard to the development of chemonuclear reactors should include: (1) minimum radioactivation and contamination of the processed chemical, (2) maximum use of reactor power as ionizing radiation in the chemical process, and (3) low cost for the radiation energy. Low cost is important because the high production capability of chemonuclear reactors limits their use to manufacturing low cost bulk chemicals.

With these goals in mind, preliminary studies were made at Atomics International of a one-thermal-megawatt chemonuclear reactor, which was dual-flow and organic liquid cooled. In this reactor, it is estimated that about 3.4% (corresponding to 34 kw) of the total radiation will be available in the chemical process stream through gamma ray absorption and the slowing down of neutrons.

The radiation power of the chemonuclear reactor was selected on the basis of findings in a report published by Arthur D. Little (1). The report states that the radiation power presently envisaged by most potential users is in the order of kilowatts to tens of kilowatts. The organic liquid cooled reactor concept was selected because of the likelihood of chemical compatibility, and the similarity of potential organic chemical process streams and the coolant.

## Reactor and process description

The chemonuclear reactor concept described in this article is shown in

Figure 1. The reactor is a basic design without any reference to a specific chemical process. Design modifications would have to be made to the reactor to suit a particular chemical reaction, depending on the pressure, temperature, phase during reaction, purification, and the residence time in the radiation field. In the basic design, the chemical process stream to be irradiated flows downward through the center tube and around the outer tube of each fuel cell as shown in Figure 2. Both the coolant and the process streams will probably operate at similar temperatures and pressures so that leakage and thermal problems are minimized. The chemical passing through the reactor does not contact the fuel cladding, thus fouling of the heat transfer surfaces by the process stream is avoided.

Diphenyl or a mixture of polyphenyls can be used for the coolant depending on the temperature of the process chemical stream.

A flow sheet for a typical chemonuclear process, without reference to a specific chemical, is shown in Figure 3. In the process envisaged, the chemical feed stream is passed through a shell-and-tube preheater to raise the temperature to approximately that of the chemonuclear reactor coolant. The chemical is then pumped through the chemonuclear reactor and discharged through a cooler. A line is provided in the exit stream to recycle the chemical through the reactor if necessary.

In a separate piping system an organic liquid coolant, such as diphenyl, is circulated through the chemonu-



Cross section of a model of the Piqua, Ohio, organic moderated reactor.

clear reactor. The heat absorbed by the diphenyl in the reactor is exchanged with water in a steam generator. A cost credit can be taken for the process steam generated from this equipment. Provision is made in the diphenyl piping system for the introduction of the makeup coolant as well as for the transfer of the coolant to a cleanup facility. In the cleanup operation, high boiler products formed as a result of radiation of the diphenyl are removed.

## Design chemonuclear reactor

The chemonuclear design is based on a modification of the core and concentric-cylinder type fuel elements developed for the Piqua OMR. This is an 11.4 electrical megawatt reactor designed by Atomics International and under construction at Piqua, Ohio. The modified fuel elements are designed for pressure considerations of about 750 lb./sq. in. in the processing stream. The fuel configuration has an I.D. at the inner steel can of 3.062 in. and an O.D. of 5.180 in. The volume fractions of a unit cell are:

Coolant (contained inside steel sleeves)	0.124
Process chemical	0.558
Fuel (U — 3.5 Mo — 0.1 Al, 18.0 g./c.c.)	0.174

Aluminum	0.136
Steel (10 mils thick)	0.008
	1.000

Nineteen fuel elements were considered for the core design, giving an effective radius of 13.75 in. for the active core. The length was set at 26 in. for an approximate optimum nuclear arrangement. This length would be increased slightly when control rod effects are considered. An infinite reflector was assumed.

Nuclear calculations were based on the two group method. Fast group cross sections were obtained from the Muft IV code in which resonance capture in U-238 for the specific geometry was included.

The principal operating data for the chemonuclear reactor are listed in Table 1.

The figure of 3.4% or 34 kw of total radiation available in the processing stream has been estimated from the Piqua OMR. This amount of radiation is conservative when compared with the total fission energy absorbed by the OMRE coolant. These figures are shown in Table 2.

Since the processing stream in the reference chemonuclear reactor represents about 82.5 wt% of the sum of the process stream and the diphenyl (Table 3) (assuming both have the same density), it is reasonable to expect that the energy absorbed by the processing stream will be somewhere between 3 and 4% of the total fission energy.

## Estimated process costs

The cost summary for the one Mwt chemonuclear reactor with 34 kw of radiation in the processing stream are listed in Table 4. The capital cost of the plant is estimated at slightly under a million dollars (\$931,000). The net total power cost consisting of the annual fixed charges on the plant capital and first core, annual fuel cycle cost, and operating and maintenance cost, less a credit for process steam (50 cents/million Btu), is \$230, 900/yr.

The operating and maintenance costs, Table 5, allow for a 3-shift operation (12 personnel), organic makeup costs, spare parts, and supplies. Overhead costs are assumed to be integrated into the general over-

head of a chemical plant where a chemonuclear reactor might be used.

At a 0.9 capacity factor, the total cost of radiation (\$/kwh) for the reference design is summarized as follows:

Fixed charges	0.52
Fuel cost	0.10
Operating and maintenance	0.29
<b>Total</b>	<b>0.91</b>
Process steam credit	0.05
<b>Net total cost</b>	<b>0.86</b>

The total radiation cost for the chemonuclear reactor is lower than the costs published by Arthur D. Little (1), for electron accelerator machines, Co-60 and Cs-137 sources which are of approximately equivalent power as shown by:

	POWER, kw	TOTAL COST, \$/kwh
Machine*	30	1.40-1.59
Co-60*	30	1.90-2.63
Cs-137*	30	2.15-3.58
Chemonuclear**	34	0.86

\* Based on 10-20% annual fixed charges on plant capital.

\*\* Based on annual fixed charges on plant capital at 14%.

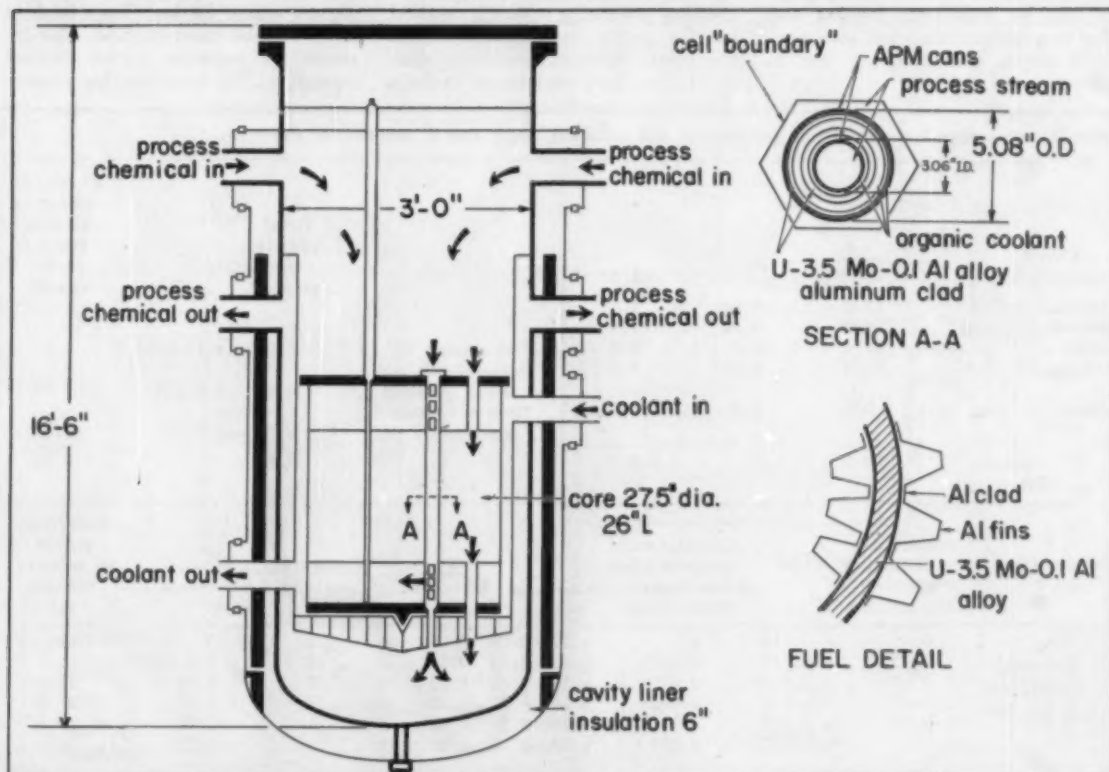


Figure 1. Sectional elevation of a proposed 1000 kw organic cooled chemonuclear reactor.

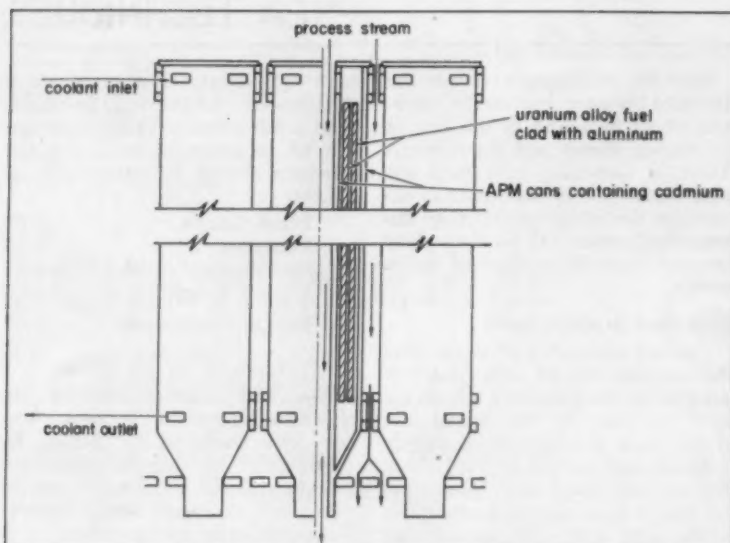


Figure 2. Three cells showing proposed flow of process stream in reactor.

### Neutron absorber-gamma emitters

As part of this preliminary study, the possibility of adding small amounts of a neutron absorbing-gamma emitter to the inner and outer processing stream guide tubes was considered (Table 3). One such material is Cd-137. Its high cross section and Mev per neutron absorbed compared to hydrogen and iron (2) are as follows:

	$\sigma$ ( $\gamma$ ), barns	Mev/absorption
Cd-113	2550	9.05
H	0.33	2.23
Fe	2.43	7.79

Such materials not only reduce the thermal neutron flux to which the chemical processing stream is exposed, but the gamma rays emitted add to the total radiation available. Also, the higher fuel enrichment reduces

Table 1. Reactor operating data.

Thermal power	1 Mw
Radiation power	34 kw
Plant factor	0.9
Core dimensions	27.5-in. diam. by 26-in. long
Fuel elements	19 Piqua-type fuel cells (modified)
Fuel	U-3.5 wt. % Mo 0.1 Al
Enrichment U-235	3.4%
Avg. exposure, Mwd/MTU	5000
Coolant	Diphenyl
Coolant velocity	7 ft./sec.
Coolant flow	$7.7 \times 10^6$ lb./hr.
Inlet temp.	485°F
Outlet temp.	493°F
Max. surface temp.	580°F
Pressure drop	2.6 lb./sq. in.
Steam generated	3120 lb./hr. 450 lb./sq. in. 456°F

Ratio of coolant to process flow area	22%
Processing dose	10 megarad*
Processing rate	2700 lb./hr.

\*One megarad = 1.26 whr/lb.

the portion of gamma ray capture in the U-238.

The effects of additional amounts of cadmium are shown in Table 4, columns 2 to 6 inclusive. The addition of cadmium to the processing tube increases the radiation power slightly above 34 kw (from 34.4 to 35.4) for the cases studied. The increase in radiation power is not enough to be attractive for chemo-

Table 3. Percentage increase in fuel enrichment and radiation power due to addition of cadmium.

CORE CONSTITUENTS	vol. %	g./c.c.	wt. %	TOTAL ENERGY (MEV/ FISSION)			ENERGY AB- SORBED IN PROCESS STREAM (MEV/ FISSION)
Organic coolant	12.4	0.84	2.5				
Process chemical	55.8	0.84	11.3				
Fuel	17.4	18.0	75.8				
Aluminum	13.6	2.72	8.9				
Steel	0.8	7.8	1.5				
	100.0		100.0				
				Fast neutron KE (4)*	5.0	x 11.3/13.8	4.1
				Instantaneous and decay gammas (6)	14.6	x 0.113	1.65
				Neutron capture gammas (6)	9.2	x 0.113	1.04
					28.8		6.79

ENRICHMENT WT. %	TOTAL GAMMA RADIATION ADDED BY CADMIUM (MEV/FISSION)	GAMMAS FROM CADMIUM ADDED TO PROCESS STREAM (MEV/FISSION)	% INCREASE	GEOMETRY FACTOR†	TOTAL % INCREASE	RADIATION POWER IN PROCESS STREAM KW
3.4	0	x 0.113	0	x 100/6.79	0	34
4.5	0.42	x 0.113	0.0475	x 100/6.79	0.7	34.4
5.2	0.62	x 0.113	0.07	x 100/6.79	1.03	34.8
6.0	0.81	x 0.113	0.092	x 100/6.79	1.36	35.0
6.9	0.97	x 0.113	0.11	x 100/6.79	1.62	35.2
7.8	1.11	x 0.113	0.126	x 100/6.79	1.85	35.4

\* All the KE associated with fission neutrons is assumed to be absorbed in the coolant and process stream (5).

† Assumed for gamma ray absorption.



Table 2. Absorbed reactor energy.

REACTOR	REACTOR POWER, MWT	% OF TOTAL FISSION ENERGY ABSORBED BY ORGANIC LIQUID	
		CALC.	MAX.
OMRE	16	7.85	10.3
OMR-Piqua	45.5	3.65	4.9

nuclear reactors based on the Piqua-type core design because the corresponding increases in the fuel cycle cost outweigh any gains. The basic reference design of 34 kw with no cadmium gives the lowest total cost/kwh (column 1 of Table 4).

However, there may be other chemonuclear designs where the use of neutron absorbing gamma emitter material may be sufficiently promising to merit further study. A case in point is a design based on an OMRE type core which uses fully enriched fuel, and which has a relatively large annular volume between the edge of the core and the reactor vessel wall. This annular volume, into which there is a high leakage of thermal neutrons from the core, can be used to augment the process chemical volume in the core proper, by permitting a portion of the process stream to flow through it. In such a design, it is suggested that a thin cylindrical

Table 4. Summary of costs for one Mwt organic chemonuclear reactor.

	REFERENCE DESIGN					
		34	34.8	35.0	35.2	35.4
kw of radiation	3.4	4.5	5.2	5.0	6.9	7.8
$U^{235}$ enrichment, wt. %	931,000	931,000	931,000	931,000	931,000	931,000
Capital cost of plant, \$	46,750	62,500	71,500	80,000	88,000	96,000
First core working capital						
Fuel element fabrication	8,350	11,700	13,900	16,400	19,200	22,190
Precore fuel inventory, \$/yr.	131,000	131,000	131,000	131,000	131,000	131,000
Annual fixed charges on plant capital at 14%	7,010	9,440	10,870	12,230	13,640	14,980
Annual fixed charges on first core at 12.7%	28,090	37,140	42,280	49,520	56,710	63,200
Annual fuel cycle cost	78,300	78,300	78,300	78,300	78,300	78,300
Operating and maintenance						
Total	244,400	255,880	262,450	271,050	279,650	287,480
Credit for process steam	-13,500	-13,500	-13,500	-13,500	-13,500	-13,500
Net total power cost, \$/yr.	230,900	242,380	248,950	257,550	266,150	273,980
kwh of radiation at 0.9 plant factor	268,000	272,000	274,000	276,000	278,000	279,000
Total cost, \$/kwh of radiation	0.86	0.89	0.91	0.93	0.96	0.98

cadmium-steel plate be installed so as to surround the core just beyond the reflector region, and that small amounts of cadmium be used at the inner walls of the reactor vessel (3). The thermal neutrons captured by the cadmium would produce gamma rays for absorption in the annular processing stream.

#### Potential chemonuclear processes

An examination of the literature for potential processes applicable to the chemonuclear reactor has been made. For almost all the studies reported in the literature, there are many questions to be resolved concerning the effects on the chemical reaction and the radioactivity of the

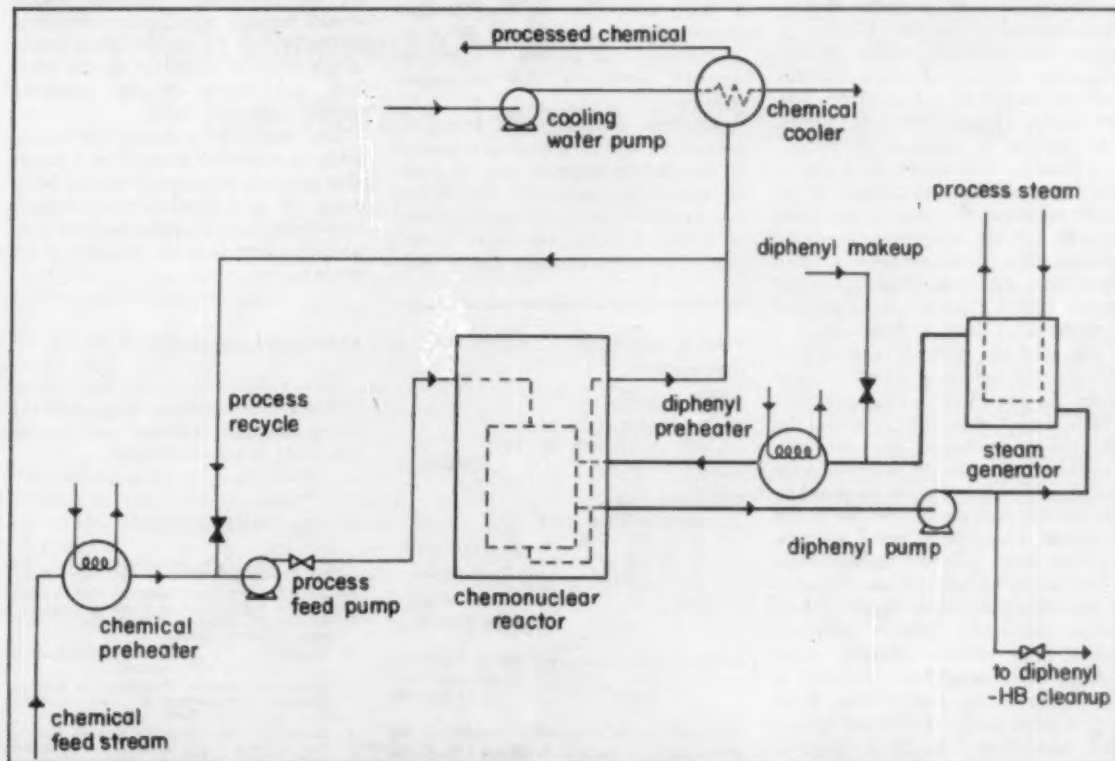


Figure 3. Typical chemonuclear flow sheet considered for processing of chemical materials.

products by varying the pressure, temperature, concentration, neutron flux, and gamma intensity. Some of these problems can be investigated by the use of radiation loops, but a complete investigation under industrial conditions would require a pilot study in a chemonuclear reactor.

Of the many chemical reactions which are accelerated by ionizing radiation, there are at least three which have a reasonable success probability. There is no guarantee of their economic superiority, but their potential looks good at this time.

**Polyethylene.** It has been shown that ethylene gas can be polymerized by radiation to solids, waxes, and liquids, depending upon the temperature. At room temperature, a solid forms which is quite comparable to commercial polyethylene. At higher temperatures one gets waxes, viscous oils; and at the highest temperatures, thin liquids. The radiation yields, G-values (molecules per 100 ev), are of the order of 1000; but the effect on these values of extremely high intensity radiation as in a reactor is not known.

Operating a reactor at room temperature to make solid polyethylene would require a fair amount of cooling and no process steam could be developed as a by-product. Making lower-molecular weight liquids at higher temperatures would permit producing by-product steam, but the question would be what to do with the liquids. These would be olefins with straight or branched chains and it is possible they might be of use in the detergent industry. There is no question about the use of the solid product, for the polyethylene plastic business has been expanding at a rapid rate. Problems of plugging the reactor with a solid should be studied in preliminary loop experiments.

Probably the severest drawback to this reaction is that ethylene is a gas under the pressures and temperatures which would be used. This means the absorption coefficient for radiation would be quite low. In order to make use of as much radiation as possible, the reactor core might well be in the center of a very large vessel containing ethylene gas, an arrangement which might be rather bulky. Because of this arrangement the reaction would utilize principally gamma radiation, rather than neutron slowing down energy which would be liberated in the coolant in the reactor core. Even with a large vessel, it does not appear that more than 1 or 2% of the total reactor power could be absorbed by the ethylene. Despite this inefficiency

of use of radiation, the value of the product justifies the selection of this process for early trial.

**Phenol.** In this reaction benzene is dissolved in water and pumped through the reactor core. The concentration of benzene is very low, but some benzene is hydrolyzed to phenol. The G-value is quite low being in the range of 2 to 3. Soviet scientists have indicated, however, that the G-value may be increased by a factor of 20 or 30 by introducing oxygen into the water and running it at high pressure and temperature.

Again a loop experiment is in order during construction of the chemonuclear reactor. Phenol is an expensive chemical used in fairly large amounts, so its production would be potentially worthwhile. Because the reactants are in the liquid phase (benzene and possibly oxygen dissolved in water), the reaction should be a good one to absorb a large amount of the available radiation. Whether process steam could be made depends upon the temperature level of the reaction, which would be determined from the loop experiments.

Since only low concentrations of phenol in water would result from this reaction, it appears that an important problem in the over-all process is the separation of the product stream. Again, preliminary loop experiments would provide an opportunity to work on this separation problem.

**Ethylene Glycol.** This important compound, which is used as a coolant in automobile engines, can be made by irradiating methanol. The G-values measured are in the neighborhood of 2, but this situation might be improved by some research under vary-

ing temperature conditions. So far, the reaction has been conducted only in the neighborhood of room temperature, so the effects of higher temperatures are not known. As in the case of the phenol, the reactant is a liquid, so it is quite simple to make use of a high percent of the available reactor radiations.

## Summary and conclusions

The one Mwt chemonuclear reactor concept offers a promising device for supplying ionizing radiation to promote industrial chemical reactions. The radiation cost for the chemonuclear reactor is lower than the costs for electron accelerator machines and radiation sources reported in recent radiation application surveys.

The chemonuclear reactor concept can be modified or tailored to the processing stream requirements of a number of reactions depending on the nature of the chemical reaction with regard to pressure, temperature, purification, phase, and residence time.

Typical reactions for possible study are the polymerization of ethylene, the reaction of benzene and water to form phenol, and the irradiation of methanol to produce ethylene glycol. Each of these processes has a distinct set of operating variables which would require specific modifications to the reactor for a pilot plant study of the effect of radiation on the reaction, the nature of the products formed, and the yields.

The first reactor should not necessarily be expected to result in a profitable process; however, it should fill in many of the gaps in technological knowledge which might be later successfully exploited in a commercial facility.

**Table 5.** Operating and maintenance cost estimate.

1. Three Shifts	
12 people at \$3/hr. for	
173 hr./month at 12	
month/yr.	\$75,000/yr.
2. Organic makeup	
allow 20%* of usual 25	
lb./Mwd 0.20 x 25	
lb./Mwd x 1 Mwt x	
365 day/yr. x 0.9 x	
\$0.17/lb.	\$ 280/yr.
	(approx. \$300/yr.)
3. Spare parts and supplies	\$ 3,000/yr.
Total	\$78,300/yr.

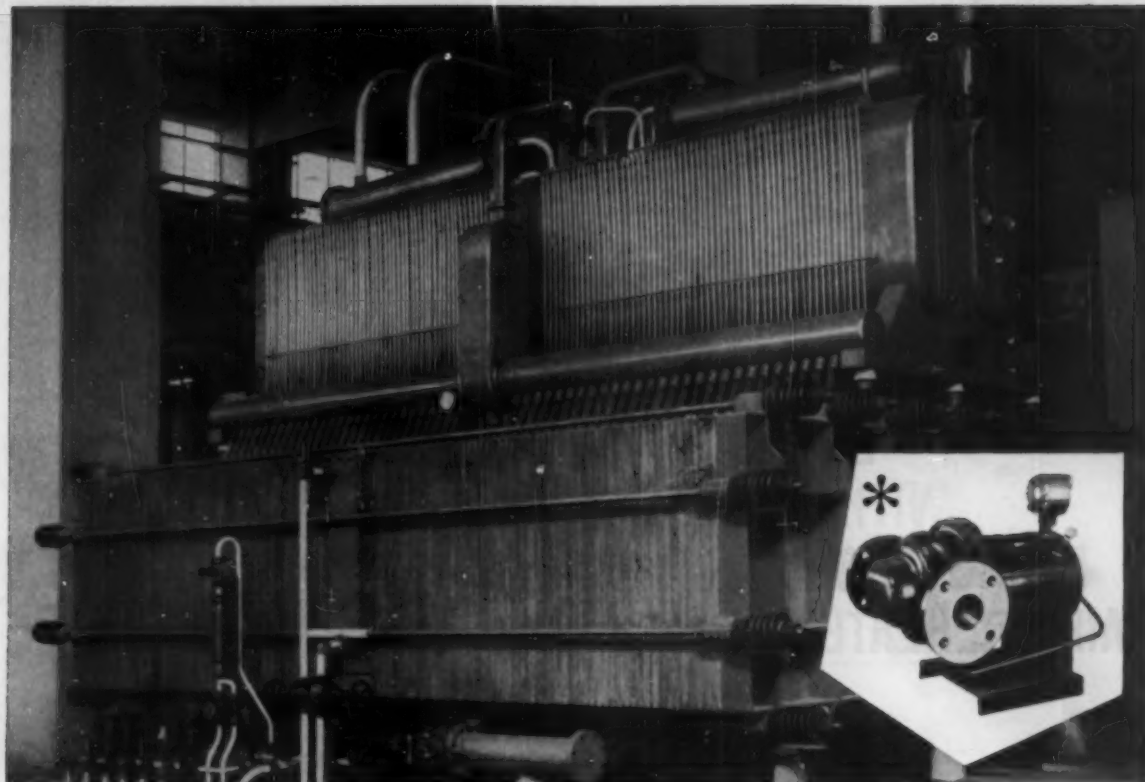
\*Organic liquid coolant is present in the chemonuclear reactor to about 18% of the total chemical process stream and coolant.

## ACKNOWLEDGMENT

The assistance of J. R. Hume, Atomics International, in performing the preliminary nuclear analysis for this study is acknowledged.

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# what's your best estimate?

... a quiz for Chemical Executives who want to keep posted

**QUESTION 1.** According to a recent survey by the Manufacturing Chemists Assn., nearly 50% of its members are engaged in, or have an interest in, foreign operations. Can you guess what per cent of total capital outlay by U.S. chemical companies in 1959 was for plants and facilities overseas?

- a \$\$\$\$\$\$ \_\_\_\_\_ 5%
- b \$\$\$\$\$\$\$\$\$\$ \_\_\_\_\_ 10%
- c \$\$\$\$\$\$\$\$\$\$\$\$\$\$ \_\_\_\_\_ 15%
- d \$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$ \_\_\_\_\_ 20%

**QUESTION 2.** How many chemical and petrochemical plants has Lummus designed, engineered and/or constructed abroad since World War II?



**ANSWERS: 1.** (c) is correct. MCA reports that an estimated 15% of the money spent by U.S. chemical companies in 1959 went for plants and facilities overseas.

**2.** The answer is (b). Lummus has designed, engineered and/or constructed 61 chemical and petrochemical plants in 11 foreign countries since 1945. Seven international members form the Lummus group of companies which circles the globe.

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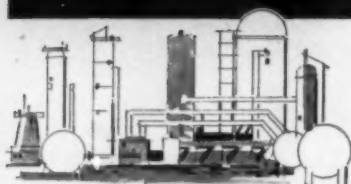


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## New ceramic — metal material of construction

Widening of chemical processing corrosion and temperature limits seen as Pfaudler unveils new ceramic-metal composite material of construction. Resistance to corrosive vapors at 1,300°F, improved impact and thermal shock properties, good heat transfer rate claimed for newly-introduced "Nucerite."

LIMITS OF CHEMICAL PROCESSING conditions promise to be widened in the near future with introduction by Pfaudler of a new family of ceramic-metal composites. Christened "Nucerite," the new material is said to offer an impressive list of advantages over existing materials of construction for certain processing equipment:

- Proved resistance to corrosive vapors at 1,300°F, with the expectation that this limit will be exceeded by several hundred degrees.
- Heat transfer rate 6 to 10 times better than most present high-temperature ceramics.

- Higher tensile strength than mild steel.

- Much improved resistance to impact and thermal shock over existing glassed metals.

The ceramic component of Nucerite is chemically bonded to steel and other heat-resistant metals such as Inconel in the same manner as Pfaudler's existing glasses. However, for some of the contemplated applications of the new material, it is probable, says the company, that certain reactive metals, such as tantalum, columbium, and molybdenum — which maintain strength well at high temperatures—

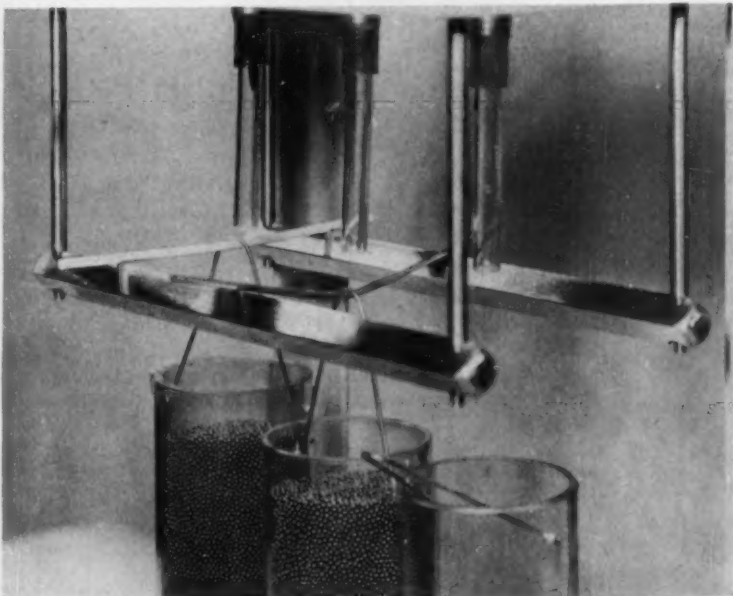


Figure 1. Results of modulus of rupture test. Glass rod (right) has broken, steel rod (center) is permanently deformed, ceramic rod (left) resists stress of 85,000 lb./sq. in. with no failure or permanent deformation.

will also be used as base metals.

The coating is sprayed onto the base metal cold as a water emulsion. After a short period of air drying, there follows a heat treatment which imparts to the material a ceramic structure characterized by a large number of very small crystals. Key to the process is preaddition of nucleating agents to control the kind and degree of crystallization. In this respect, the new material would seem to bear at least a distant relation to "Pyroceram", unveiled by Corning Glass about three years ago. (CEP, July 1957, page 80). However, up to now at least, Corning Glass has concentrated on development of Pyroceram as a self-sufficient material of construction. Pfaudler, on the other hand, regards Nucelite as a ceramic-metal composite material.

#### Over the test course

Among the controlled laboratory tests carried out at Pfaudler's Rochester, N.Y., labs were:

**Point impact tests.** A .22 caliber rifle fired from a distance of 25 feet at a Nucelite plate (.020 inch ceramic coating on 3/8 inch Inconel), crushed the surface only slightly, exposed no metal. In a second test, a 2-inch-diameter steel ball of 1.2 lb. was dropped from a height of 9 feet onto a Nucelite sample and onto a 3/8 inch thick piece of safety plate glass. The safety glass shattered completely, while the Nucelite sample was only slightly crushed at the outer surface.

**Modulus of rupture test.** Rods of soda lime glass, mild steel, and the ceramic component of Nucelite were suspended across parallel knife edges. Lead shot was added gradually to each of the plastic cylinders suspended from the rods. The glass rod broke at approximately 25,000 lb./sq. in., the mild steel rod was permanently deformed at 85,000 lb./sq. in., while the Nucelite rod withstood an 85,000 lb./sq. in. stress without failure or permanent deformation (Figure 1). The rod bent about 1/8 in. under stress, but returned to its original shape upon removal of the load.

**Thermal shock test.** A Nucelite sample (.020 inch ceramic coating on 1/2 inch mild steel plate) was heated for 15 minutes at 1,250°F. Immediately on removal from the furnace, ice water was poured over the plate. No visible damage at a  $\Delta T$  of approximately 1,200°F.

**Abrasion test.** In standard abrasion tests, Nucelite resulted 4 times more

*continued on page 82*

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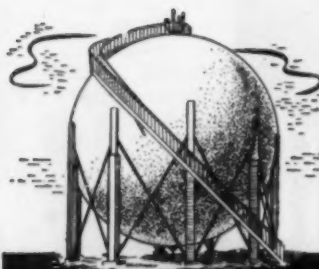
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## New materials

from page 81

abrasion-resistant than regular laboratory glass.

**Heat transfer test.** Two identical beakers of water each containing 300 ml of water were heated to 212°F on a constant-heat hot plate. After 30 minutes at this temperature, one of the beakers which rested on Nucelite (.020 in. ceramic on 3/8 in. Inconel) contained 10 ml. of water. The second beaker which rested on solid 3/8 in. porcelain, contained 170 ml., demonstrating that Nucelite has many times the heat transfer rate of porcelain.

**High temperature oxidation test.** Samples of molybdenum and Nucelite (Figure 2) were subjected for five minutes to an oxy-acetylene flame



**Fig. 2.** Oxy-acetylene flame at 1,600°F plays on Nucelite sample during high-temperature oxidation test.

(1,600°F). The molybdenum sample was severely oxidized, while the Nucelite was unaffected.

### Not yet commercial

Small reaction vessels and heat exchanger tubing, says Pfaudler, have been successfully coated and tested. These results however, emphasizes the company, were obtained and confirmed in carefully controlled laboratory and field tests. In the works is "an extended evaluation period of selected field testing in the U.S.," to be followed by establishment of production facilities in all of Pfaudler's domestic and foreign plants. Eventual applications are predicted, not only in chemical processing as such, but also in nuclear and space technology.

#



# **HYPALON<sup>®</sup>** pump linings outlast hard rubber 8-to-1 in caustic soda-chlorine unit

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HYPALON is resistant to corrosive chemicals, abrasion, ozone, sunlight, weather, high temperature (see chart). All this—plus its flame resistance and permanent colorability—makes it an extremely versatile elastomer. Rubber maintenance products which offer long-term economy of HYPALON and neoprene are available from your rubber goods distributor. He can suggest the right product for any job.

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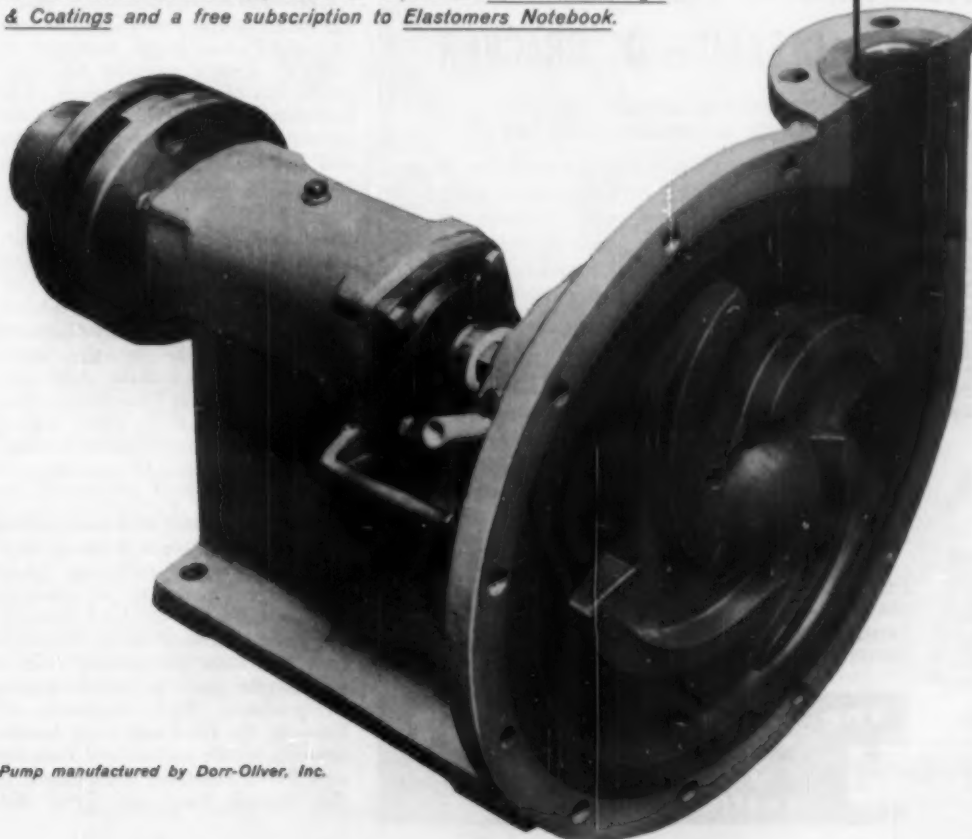
Sunlight and Weather

Resistance . . . . . Outstanding

Abrasion Resistance . . . Excellent

Oil Resistance

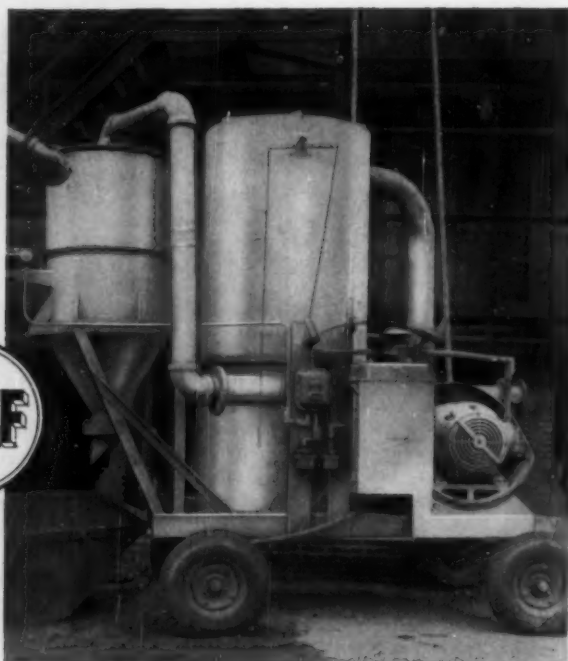
Good to Excellent



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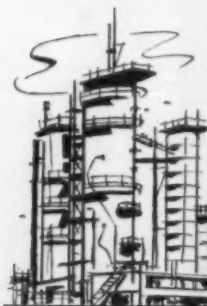


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### industrial news

Another phenol plant will be added to Argentina's growing market when plans are completed by Hooker Chemical and Atanor, one of Argentina's largest corporations. A new company formed for this purpose will begin manufacturing when negotiations wind up for a loan to purchase equipment between the Export-Import Bank in Washington, D.C. and Duranor. The 25 metric tons a day plant will use the Hooker phenol process. This is based on the Raschig process. Construction at one of Atanor's already established plants is slated to begin in July, finish within two years.

A synthetic rubber latex plant is planned in the Midlands of England by Witco Chemical Ltd. On-stream operations are scheduled to begin early in 1961, with initial capacity 8 million pounds dry weight. The output will be butadiene-styrene, high styrene, nitrile and other acrylic types of latices.

Commercial production of liquid helium and liquid hydrogen begins at Air Products Iselin, New Jersey, plant. The plant will produce liquid helium at  $-452^{\circ}\text{F}$ . and liquid hydrogen at  $-423^{\circ}\text{F}$ . Design permits increased production of one liquid when none is required of the other. Specially designed vacuum-insulated containers will deliver by truck within a 600 mile radius, with air freight used for longer distances.

Two plants to be built in Holland: a sulfuric acid contact plant, capacity 100,000 MT/year, another for decomposing sulfuric acid refinery sludge, will be designed by Chemico. Operation will be by the newly formed Albatros Sulfuric Acid and Chemical Works at Vlaardingen, Holland. The company is jointly owned by Albatros Superfosfaatfabrieken N.V. of Utrecht, and Cyprus Mines of California.

A boost in benzoic acid and sodium benzoate production is in the cards at Heyden Newport, with new plant construction underway at Garfield, N.J. In addition to the food preservative angle, increased use in the plasticizer and resin intermediate field is seen for the grade of benzoic acid to be produced. Both chemicals are listed by the Food and Drug Administration as safe and exempt from the new Food Additives Amendment to the Federal Food and Drug Act.

For more information, turn to Data Service card, Circle No. 72

# MATHESON

## Compressed Gas Notes

### Flowmeter Calibrations now available for specific gases

For the past several months, the Matheson Engineering Department has been engaged in calibrating our Series 600 flowmeter tubes for a large number of gases at flow conditions of atmospheric pressure at 70° F. Using our six flowmeter tube sizes (with two floats each) we have obtained information for almost 1,000 different calibrations.

These curves are available for a specific gas, for a given Series 600 flowmeter tube at \$1.00 each. Calibration curves for air and water are now provided with each tube at no charge. The Guaranteed Interchangeability of Matheson flowmeter tubes makes this calibration service especially useful. Matheson Series 600 flowmeter tubes of the same number are guaranteed interchangeable to  $\pm 2\%$ . Thus, calibration data remains unchanged regardless of the number of tube replacements.

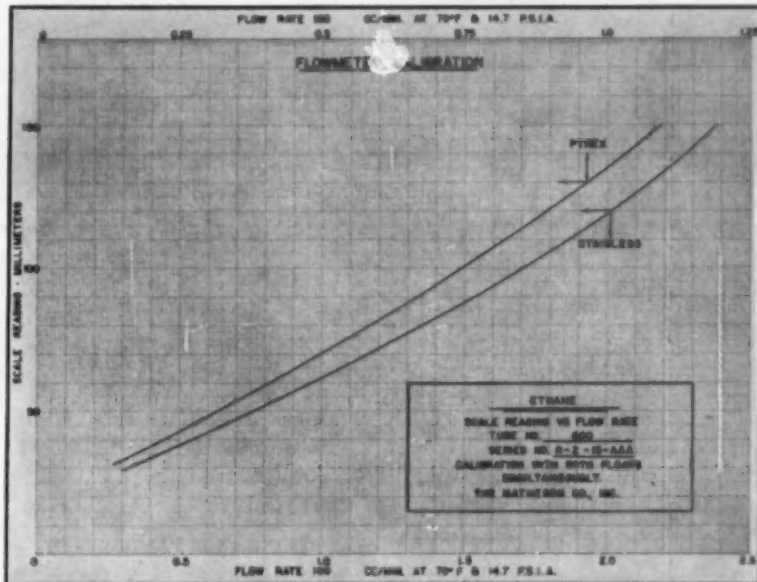
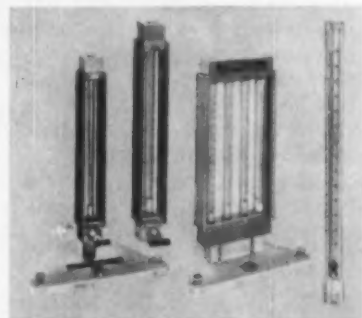
#### Special Calibration Services

Further calibration service is offered on an individual basis. Calibration curves for gas mixtures, or for gases at flow conditions other than atmospheric pressure at 70° F. can also be furnished. Prices on request.

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# COMPUTER PROGRAM abstracts

The Machine Computation Committee of the A.I.Ch.E. is interested in receiving program abstracts for publication as part of its program interchange activity. Details of this activity are given in the *Guide to Abstracts and Manuals for Computer Program Interchange*, which has just been revised based on experience during the first year the interchange has been functioning. Copies of the new *Guide* are available at no cost from the A.I.Ch.E. in New York.

Once again the Committee wishes to emphasize the three rules for participation in the interchange program:

- 1) Abstracts submitted for publication must follow the form shown in the *Guide*.
- 2) The submitter of the abstract agrees to make available for publication a program manual, prepared as described in the *Guide*, should sufficient interest develop.
- 3) Abstracts for publication, and all questions concerning published abstracts, must be sent to the Machine Computation Committee c/o A.I.Ch.E.

Two manuals are now available: *Line Sizing and Liquid-Liquid Heat Exchanger Design*. The latter is described July p. 161. Scheduled for completion before the end of the year are manuals on *Multicomponent Distillation (Abstract 020)*, *Nonlinear Estimation (016)*, *Piping Flexibility (002)*, and *Plate-to-Plate Distillation Procedure (017)*.

## Platinum resistance thermometer conversion table (038).

William I. Martin  
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**Description:** The program calculates a conversion table of temperature versus resistance in units of 0.01 ohms over whatever range is desired. The basic formula used is the modified Callender devised by Van Dusen and given in National Bureau of Standards Notes to Supplement Resistance Thermometer Certificates.

**Computer:** IBM 650 basic.

**Program Language:** SOAP II.

**Running Time:** Fifteen minutes for a 600° Table from -150 to +450°C.

**Comments:** The temperatures are reported as functions of even 0.01 ohms of resistance thus facilitating easier use of tables than those presently prepared by NBS.

**Availability:** A manual will be pre-

pared for publication if a sufficient demand develops.

## A design method for economical drying of moisture from solids (057).

Herbert T. Bates  
Kansas State University  
Dept. of Chemical Engineering  
Manhattan, Kansas

**Description:** There are two programs. One is for counterflow drier design, and one is for parallel flow drier de-



sign. Both require a consistent set of 12 data in floating point notation. These include the flow rates, temperatures, free moisture contents, the latent heat of vaporization of water, the humid heat of air, and the parameter M. Calculation of the di-

mensionless ratios  $hA/Gs$  for the surface drying zone and the interior drying zone for slabs, cylinders, and spheres follows the equations presented in *CEP*, July 1960, pages 52 to 57. The programs contain the sub-routines for calculating logarithms, cube roots, arctangents, and series.

**Computer:** IBM 650 floating point 2000 word capacity.

**Program language:** SOAP.

**Running time:** Reading in the program and data cards takes about 5 minutes. Calculation requires about 20 seconds.

**Comments:** In case a problem with FI <FC follows one with FI> FC it is necessary to reset location HAC to zero.

**Availability:** A manual will be prepared for publication if sufficient interest develops.

## Molecular weight by light scattering (062).

Diana M. Mahon and  
Howard T. Oakley  
Esso Research and  
Engineering Company  
Chemicals Research Division  
P. O. Box 51  
Linden, New Jersey

**Description:** This program calculates and plots the data needed to obtain the weight average molecular weight of polymers by light scattering. Data are plotted as outlined by Zimm (Zimm, B. H., *J. Chem. Phys.* 16, 1093 (1948)).

**Computer:** IBM-704, 32K core, 7 tapes.

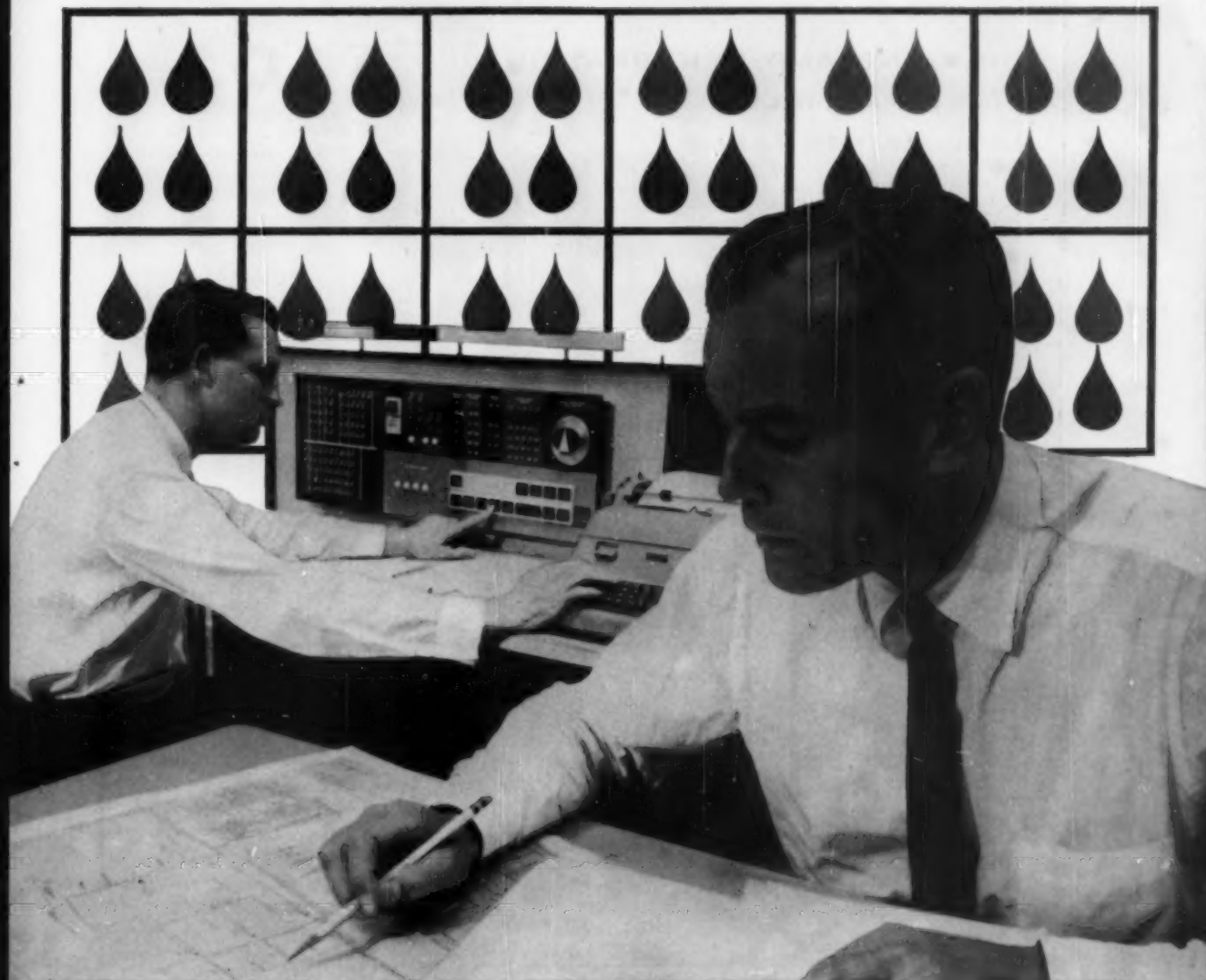
**Program language:** Fortran I.

**Running Time:** Approximately two minutes for maximum allowable number of concentrations (6) and angles (20).

**Comments:** Measurements can be made on twenty angles; up to six galvanometer readings per angle for both solvent and solution are allowed.

*Continued on page 88*





## Low-cost IBM 1620 solves gasoline blending problem

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The low-cost IBM 1620 Engineering Computer takes into account possible solutions to a blending problem and computes your most profitable operating plan.

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THE IBM 1620 is an economical, desk-size engineering computer with features previously found only in larger systems. It offers solid state design, magnetic core storage and high-speed internal computing performance. Its versatility and ease of operation recommend it for such petroleum industry applications as distillation problems, unit correlations, evaluation of options and determination of equipment efficiency.

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CHEMICAL ENGINEERING PROGRESS, (Vol. 56, No. 10)

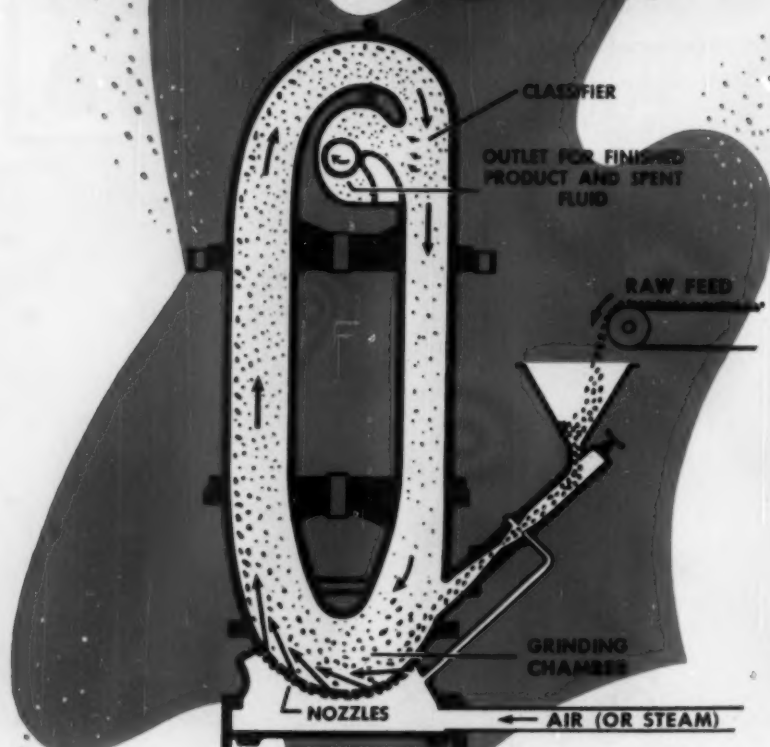
October 1960

87

for

# GRINDING AND DEHYDRATION FINER PARTICLES LOW MAINTENANCE

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| • Ceramic     | • Pharmaceutical | • Carbon  | • Chemical |

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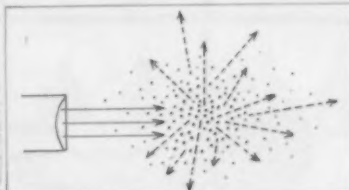
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(Formerly known as the Wheeler-Stephano Mill)

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## Computer abstracts

from page 86

able. If there are no filter factors at some angle measurements, a zero must be inserted on data form. There must be the same number of cards per set



for angles, galvanometer readings and filter factors.

Availability: The manual on this program can be made available for publication should sufficient interest develop.

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New York 36, New York

I am interested in computer program manuals corresponding to the following abstracts:

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- ☐ Molecular weight by light scattering (062)

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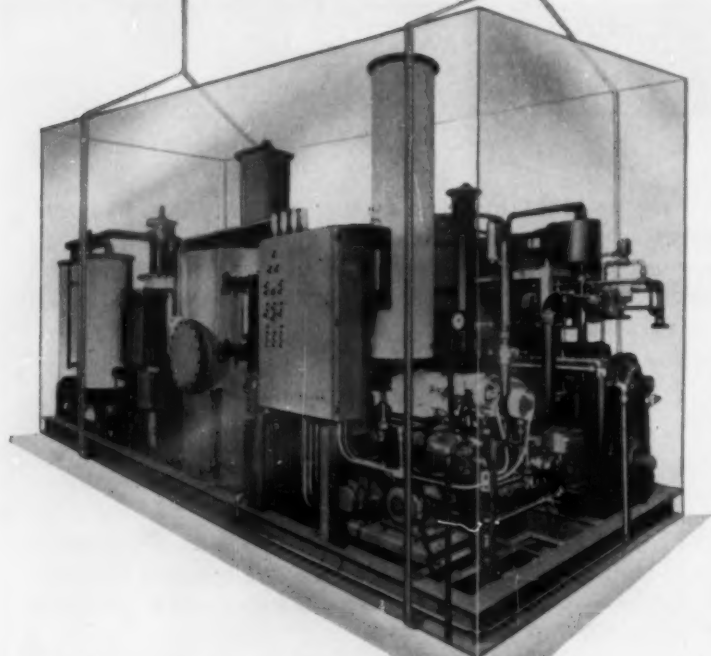
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## industrial news

A 35,000 bbl./day refinery will be built near Karachi by Kellogg International Corp., for Pakistan Refinery Ltd. The refinery is planned to consist of a crude distillation unit, a catalytic reforming unit and a hydrotreater.

A long term research program to advance fuel cell technology has begun at Battelle Memorial Institute. Described as a major effort, underwritten by some 25 companies, the program is on a five year schedule. It is fundamental in nature and designed to complement existing government, industrial and academic studies on fuel cell technology. Aspects of the program are a study of the internal electronic structure of alloys; obtaining a better understanding of the properties of materials required in a cell. Another approach is the study of thin films of metals, and of active carbon electrodes with metalchelate surfaces. Supporting the research program are major American and European industrial organizations, including chemical, petroleum, and mechanical equipment.

Stero regular synthetic rubbers will be made at a pilot plant now under construction at U. S. Rubber, Baton Rouge, La. Initial production will be the ethylene-propylene types and synthetic balata. Completion is scheduled for the end of 1961.

Facilities have just been completed at Enjay Chemical's Bayway Refinery, Linden, N. J. for producing acetone. Capacity is in excess of 100 million pounds annually.

Liquid hydrogen is now in full scale production at Linde's new Torrance, Calif. plant, with shipments totalling over 300,000 pounds already delivered to west coast missile development projects. One of the first privately owned and operated facilities to supply liquid hydrogen on a commercial basis, the plant has a capacity of 13,000 pounds a day.

A 350 tons a day capacity ammonia plant is planned by U. S. Phosphoric Products in Tampa, Fla. With natural gas as a raw material, the unit will feature an ammonia synthesis converter with one of the largest single designed capacities in the world. The product ammonia will be stored in a specially designed atmospheric storage system. Target date for completion of the Chemico designed plant is late 1961.





## HOW TO SLEUTH OUT THE TRUTH ABOUT EXPANSION JOINTS



1

### Case the joint (design, that is)

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2

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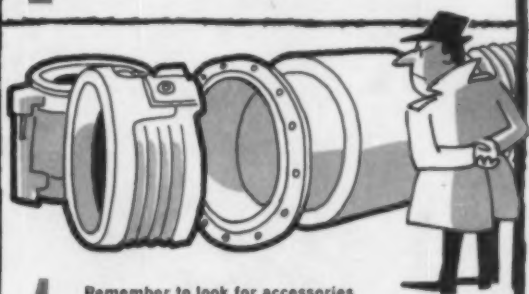
S-R Joints have no bulky castings . . . weigh up to 50% less . . . diameter equivalent to pipe flange. Installation is easier, lighter supports required.



3

### Search for clues in fabrication methods

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4

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5

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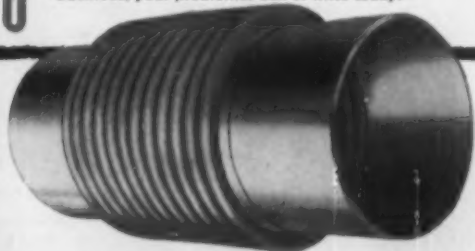
Badger's 50-year experience includes development of first successful self-equalizing design for higher pressures, temperatures. Badger has had more fabrication and engineering experience in more different applications than any other manufacturer.



6

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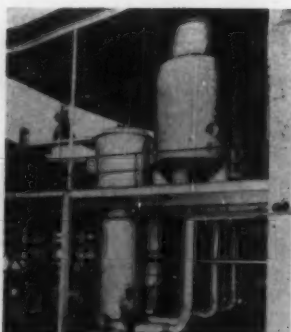
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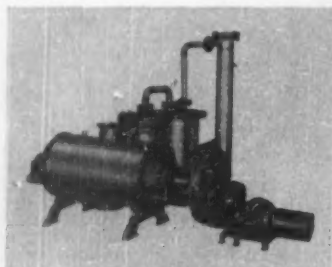
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# G-B

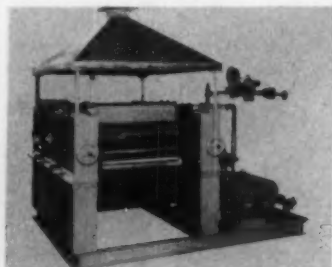
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## industrial news

A 40% increase in facilities is under construction at Perkin-Elmer Corp., in the Electro-Optical Division. A new plant, located on a 16-acre site in Wilton, Conn. will be occupied by the engineering and advanced research and development groups.

Synthetic rubber latex will be manufactured by a new English company. An 8 million pound annual capacity plant, to be built on a 20-acre site in the Midlands of England, will put out butadiene styrene, high styrene, nitrile and acrylic types of synthetics. The company is jointly owned by Witco Chemical and U. S. Rubber.

A new ethylene and ethylene oxide plant at SunOlin Chemical will be located adjacent to Sun Oil's refinery at Marcus Hook, Pa. The plant's design capacity is 225 million pounds of ethylene and 55 million pounds annually of ethylene oxide. Existing facilities will be modified to permit production of 12 million cubic feet of high purity hydrogen and up to 1 million cubic feet of carbon monoxide a day. Included in the expansion is a multiple pipe line crossing beneath the Delaware River from the plant site to New Jersey.

A polypropylene manufacturing unit at Rotterdam, The Netherlands, is planned by a new joint company. Formed by Montecatini, and Bataafse Petroleum Maatschappij N. V., the company will be operated in conjunction with Shell Nederland Raffinaderij N. V. at Rotterdam. Sales will be through the existing Royal Dutch and Shell organizations.

A line of granular zircon material has been acquired by Metal & Thermit with their recent purchase of Orefraction Minerals, Inc. The expansion into the minerals field brought them the facilities and resources of the company which supplied the refractory, ceramic, glass and foundry industries.

A bromine plant expansion at El Dorado, Kansas, doubles capacity of the facility. The venture, jointly executed by Michigan Chemical along with Murphy Corp., also increased transportation facilities by doubling the tank car fleet.

Reagent chemicals will be manufactured and distributed by a new Brazilian firm. The joint company, Baker-Herzog Produtos Quimicos, Ltda. was organized by J. T. Baker Chemical and B. Herzog Comercio E Industria, S. A., Brazil.

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## SUBJECT GUIDE to advertised products and services

### EQUIPMENT

**Blenders, rotary** (p. 106). Nine standard models, capacities to 900 cu. ft., automatic or manually controlled operation. Bulletin 080B from Sturtevant Mill. Circle 28.

**Burner, sulfur, jet-type** (p. 110). In range of sizes up to 50 tons of sulfur per day. Bulletin 100 from Chemipulp Process Inc. Circle 40.

**Castings, high-alloy** (p. 105). Duraloy specializes in chrome iron and chrome nickel castings, also centrifugal and shell molded castings. Technical data. Circle 14.

**Coils, heat-exchange** (p. 82). Aerofin Corp. offers technical details on its manufacturing and testing services. Circle 3.

**Columns, extraction** (p. 107). Bulletin T-1159 from General American Transportation gives details of RDC columns for liquid-liquid, liquid-solid, liquid-slurry extraction. Circle 116.

**Comparators** (p. 100). Fast easy tests for pH, chlorine, phosphate. Handbook (101 pages) from W. A. Taylor gives theory and application of pH control. Circle 96.

*continued on page 94*

### MATERIALS

**Absorptive, non-swelling** (p. 22). Technical info from General Reduction Co. on chemical and physical properties of Montmorillonite. Circle 38.

**Defoamers, silicone** (p. 130). Dow Corning offers new manual on foam control. Circle 79.

**Gases, compressed** (p. 85). Catalog from The Matheson Co., Inc. gives details on 87 compressed gases, flowmeters, accessories, pressure regulating equipment. Circle 113-1.

**Gases, compressed, handling of** (p. 85). The Matheson Co., Inc. offers Wall Chart on "Safe Handling of Compressed Gases." Circle 113-3.

**Phosphoric Acid, wet-process** (p. 19-20). Info from U. S. Industrial Chemicals on new process to make diammonium phosphate from wet process phosphoric acid without purification step. Circle 118-1.

**Porcelain, chemical** (p. 29). Lapp Insulator offers descriptions, specifications, of chemical porcelain in "customized" shapes. Circle 69.

*continued on page 94*

### SERVICES

**Design and Construction** (p. IBC). Info from Ralph M. Parsons details its world-wide facilities for design, engineering, construction of process plants. Circle 73.

**Design and Construction, process plants** (p. 79). Info from Lummus. Circle 47.

**Design and Construction, process plants** (p. 109). Technical data and info on use of model techniques in design. M. W. Kellogg. Circle 9.

**Fabrication, heat transfer equipment** (p. 92). Technical details from Goslin-Birmingham on evaporators, vacuum rotary and drum dryers, heat exchangers, flakers. Circle 13.

**Fabrication, process equipment, aluminum** (p. 81). Data from Edw. Renneburg & Sons on all-aluminum dryers, coolers, and cyclonic separators for processing urea. Circle 52.

**Semiconductor Research** (p. 21). Info from General Motors Research Labs on new cadmium sulfide compound semiconductors. Circle 91.

**Transportation, water** (p. 118). Info from National Marine Service on all water transportation requirements. Circle 43.

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#### EQUIPMENT from page 93

Compressors, diaphragm (p. 131). Bulletin 5 C from Pressure Products Industries gives complete technical info on Q-Series two-stage diaphragm compressors. **Circle 44.**

Computer (p. 14). Complete info from Bendix Computer Div. on the low-price G-15 model. Many programs available for use in chemical field. **Circle 8.**

Computer, engineering (p. 87). Prints out complete description of optimum solution. Info from IBM on its model 1620. **Circle 70.**

Control, condensate (p. 142). Technical data from The Swiss Colony on the new "Temp-A-Sure" condensate control. **Circle 114.**

Control, level, solids (p. 102). Catalog and Application Data from FloTronics gives details of the Flo-Level Model L-400 electronic controller. **Circle 20.**

Controls, liquid-level (p. 116). Bulletin F-4A from Fisher Governor gives details of Type 2500-2502 Level-Trol. **Circle 74.**

Controller, pH (p. 23). Technical data from Foxboro on new "Dynalog" pH indicator and controller. Data Sheet. **Circle 85.**

Control Systems, electric (p. 113). Bulletin CP-3708 from Vapor Recovery Systems gives full technical details of the "Varelectric Series 880." **Circle 50.**

Control Systems, visual (p. 143). Booklet BE-40 from Graphic Systems describes the "Boardmaster." **Circle 92.**

Conveyors, belt (p. 32). Catalog Data from Stephens-Adamson. **Circle 29-2.**

Conveyors, closed-belt (p. 32). Conveyor-elevator Bulletin 349 from Stephens-Adamson. **Circle 29-1.**

Conveyors, pneumatic (p. 84). Bulletin 143B from Spencer Turbine. **Circle 72-2.**

Couplers, quick (p. 143). Info from OPW-Jordan. **Circle 94.**

Crushers and Shredders (p. 135). For every application and capacity. Info from American Pulverizer. **Circle 89.**

Cryogenic Equipment. (p. 96). Details from Ryan Industries on cryogenic equipment including 106,000 SCF liquid oxygen customer station. **Circle 31.**

Cylinder Valve Outlets (p. 85). Bulletin from The Matheson Co., Inc. **Circle 113-2.**

Demineralizers, package (p. 124). Details of Two-Bed and Un-A-Bed demineralizers from Hungerford & Terry. **Circle 54.**

Dryers (p. 28). Details of many types from C. G. Sargent's Sons. **Circle 30.**

Dryer, rotary (p. 108). Paul O. Abbe offers Folder C with full details of "Rota-Cone" blenders and vacuum dryers. **Circle 53.**

Dust Collectors (p. 18). Bulletin 52A-1 gives details on the "Mikro-Pulsaire" dust collector. Pulverizing Machinery Co. **Circle 18.**

Electrolytic Conductivity Equipment (p. 137). Details on many types from Industrial Instruments, Inc. **Circle 21.**

Feeders (p. 5). Catalog 804 from B. F. Gump gives details of the Draver feeder, available with automatic controls. **Circle 93.**

Filters (p. 99). Basic vertical and horizontal tank leaf filter designs in many materials including zirconium, titanium, polypropylene, PVC. Details from Buffalo Filters. **Circle 4.**

Filters (p. 103). Bulletin EP-100 from Industrial Filter & Pump Mfg. gives details of Type 152 filters and accessories, including rapid cleaning devices. **Circle 6.**

Filter Elements, corrosion-resistant (p. 121). Porosity range 1 to 100 microns, Pyrex and Teflon construction. Bulletin FPT-2 from Chem Flow. **Circle 42-2.**

Filter Paper (p. 13). Eaton-Dikeman offers 24-page Catalog 357 on industrial filter papers. **Circle 88.**

Flow Meters (p. 122). Bulletins FI-56 and J-56 from Hetherington & Berner gives details of multi-valve "Fluidometer" systems, jacketed pipe and fittings. **Circle 10.**

Furnaces, industrial (p. 123). Bulletin 100BB from Despatch Oven gives full technical details. **Circle 71.**

Fused Quartz Ware (p. 135). Technical info from Thermal American Fused Quartz. **Circle 110.**

Gas Generators (p. 90). Packaged units for production of reducing, nitrogen, carbon dioxide, hydrogen, inert and annealing atmospheres. Technical data from Gas Atmospheres, Inc. **Circle 80.**

Heat Exchangers (p. 4). Downingtown Iron Works offers technical bulletins on heat exchanger design. **Circle 39.**

Heat Exchangers (p. 24-25). Info from Patterson-Kelley on new heat exchanger manual, available on letterhead request. **Circle 45.**

Heat Exchangers (p. 97). Bulletin 132 from Niagara Blower gives details of the "Aero" heat exchanger, independent of more than a nominal water supply or disposal system. **Circle 33.**

Heat Exchangers (p. 106). Info from Western Supply, Heat Exchanger Div., on cost economics in design of heat exchangers. **Circle 123.**

Heat Exchangers (p. 120). In all grades of carbon, alloy and stainless steels, nickel, aluminum, special low-temperature materials. General Catalog from Engineers and Fabricators. **Circle 37.**

Heat Exchangers, standardized (p. 137). Bulletin 820 from Manning & Lewis gives technical details of complete line. **Circle 111.**

Heating Units, induction (p. 132). Catalog from Lepel High Frequency Laboratories gives technical details of high-frequency induction heating units. **Circle 81.**

Idlers, conveyor, pre-lubricated (p. 80). Available in 20, 35, and 45° equal and unequal length rolls with various roll diameters and thicknesses of tubing wall. Info from Transall, Inc. **Circle 27.**

Isotope Analysis Unit (p. 125). Ionization chamber instrument for measurement of alpha, beta, or gamma radiation. Details from Landsverk Electrometer Co. **Circle 109.**

Jet-Venturi Equipment (p. 12). Info from Croil Reynolds on jet refrigeration, compressors, condensers, heaters, pumps, mixers, reactors, absorbers, fume scrubbers, special jet venturi units. **Circle 41.**

Joints, expansion (p. 91). Technical info from Badger Manufacturing. **Circle 78.**

Kettles (p. 134). Info from Hubbert on single shell or steam-jacketed kettles, tanks, and vessels for chemical processing. **Circle 115.**

Kettles, processing (p. 122). Bulletin 600 from Bethlehem Foundry & Machine gives specs of kettles for reaction, agitation, heat transfer, distillation, sublimation, crystallization, drying. **Circle 112.**

*continued on page 96*

#### MATERIALS from page 93

Sodium, handling of (p. 19-20). U. S. Industrial Chemicals offers Brochure "Handling Metallic Sodium on a Plant Scale." **Circle 118-2.**

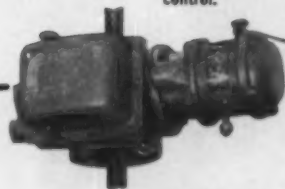
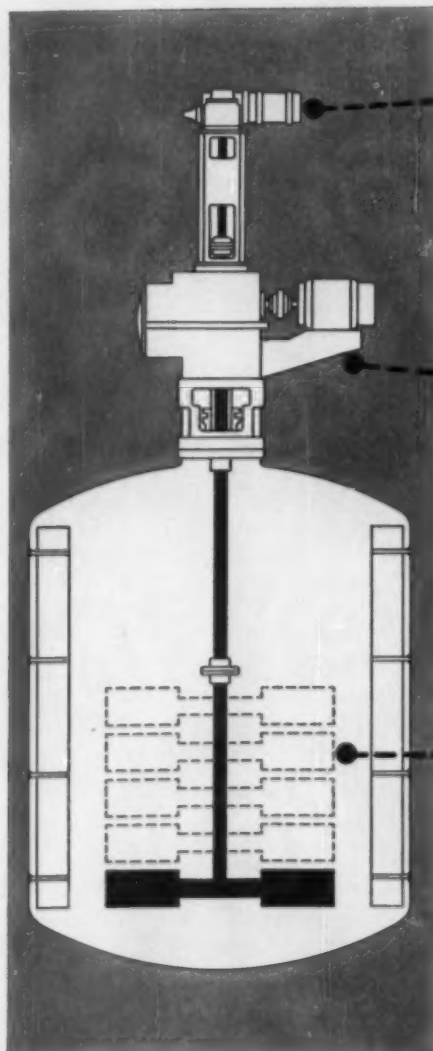
Sulfur (p. 9). New cadmium sulfide transistors prove importance of sulfur in the electronics field, Texas Gulf Sulphur. **Circle 16.**

Synthetic Rubber (p. 83). Du Pont offers Booklet "Protective Linings & Coatings" with full details on properties of "Hypalon" synthetic rubber. **Circle 15.**



# NOW...you can raise and lower mixing impellers with no process interruption...

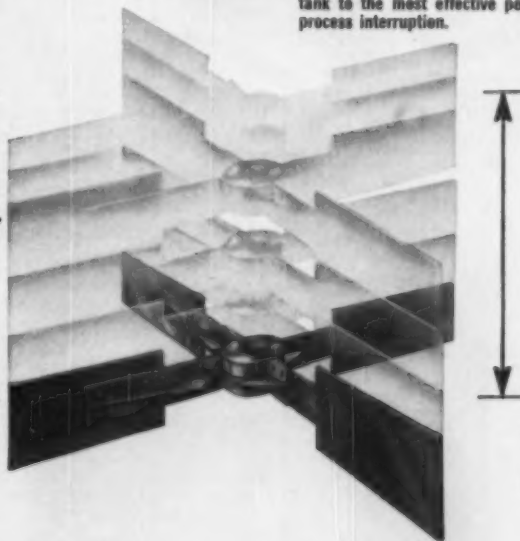
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Philadelphia mixer drive rotates shaft—applies full torque at all shaft positions.



Mixing impeller can be raised or lowered in the tank to the most effective position... with no process interruption.



This combination of Philadelphia Mixer power transmission components gives you optimum mixer performance at all times. Mixing can continue at full tank pressure while impeller position is changed, and there is no danger of product contamination because it can be done without opening the tank.

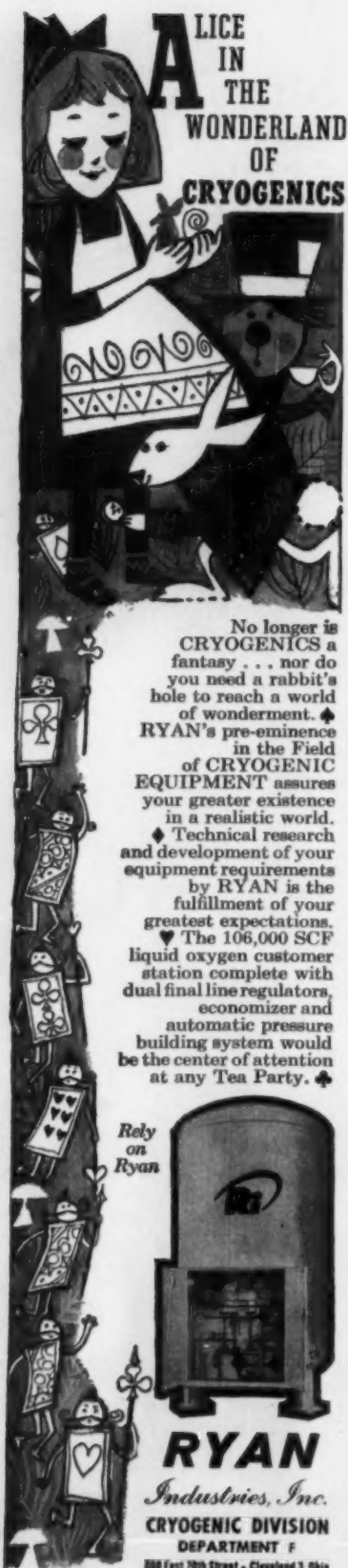
Many processors are already taking advantage of this unusual mixer design feature. Why not learn how Philadelphia lifting-lowering mixers can improve the effectiveness of your mixing operations. For full information, send for Bulletin LL-60.

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For more information, Circle No. 31

## CEP'S DATA SERVICE—

### Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

#### EQUIPMENT from page 94

**Meters** (p. 8). Data from Howell Instruments on the "Milli-V-Meter" for indication of frequency, temperature, flow, level, pressure, rev./min., weight. **Circle 7.**

**Meters, liquid-level** (p. 90). Bulletins from Uehling Instrument on the "TankoMeter" for measuring tank contents from any distance away. **Circle 26.**

**Mills, cage** (p. 128). High capacity, low maintenance, economical operation, low horsepower. Details from Stedman Foundry and Machine. **Circle 55.**

**Mills, pulverizing, fluid-energy** (p. 88). Complete details from Fluid Energy Processing & Equipment on "Jet-O-Mizer" mills, "Jet-O-Clone" dust collectors, testing and custom grinding services. **Circle 36.**

**Mixers** (p. 30-31). Simpson Mix-Muller Div., National Engineering, offers Bulletin with full technical details of new continuous "Multi-Mull" unit. **Circle 11.**

**Mixers** (p. 95). New development allows raising and lowering of impellers with no process interruption. Full details in Bulletin LL-60 from Philadelphia Gear. **Circle 87.**

**Mixers** (p. 119). Bulletin 620 from Eastern Industries has specifications of side-entering and top-entering types. **Circle 22-2.**

**Mixers** (p. 119). Eastern Industries offers Handbook of Fluid Mixing. **Circle 22-1.**

**Mixers, portable** (p. 117). Info from Gabb Special Products on line of "Shear-Flow" portable mixers. Three basic models for from 1 to 250 gallons. **Circle 35.**

**Mixers, portable** (p. 119). Revised Bulletin 530 from Eastern Industries gives technical data on complete line. **Circle 22-4.**

**Mixers, portable** (p. OBC). New design portable mixer now available from Mixing Equipment Co. in sizes from 1/8 to 3 hp, gear or direct drive. Bulletin B-520. **Circle 51.**

**Mixers, turbine** (p. 119). From 1/4 to 40 hp. Bulletin 1210 from Eastern Industries. **Circle 22-3.**

**Nozzles, spray** (p. 26). Catalog 24 from Spraying Systems has complete technical info on thousands of standard types and capacities. **Circle 12.**

**Nozzles, spray** (p. 98). Complete Catalog from Monarch Mfg. Works. **Circle 34.**

**Nozzles, spray** (p. 110). Comprehensive Catalog from Binks Mfg. **Circle 5.**

**Pall Rings, plastic** (p. 36). Technical data from U. S. Stoneware on Pall rings in polypropylene, rigid PVC, polystyrene. **Circle 2.**

**Piping, Teflon-lined** (p. 10-11). Technical info from Resistoflex on "Fluoroflex-T" piping, complete systems for corrosion control. Handle corrosives up to 500°F. **Circle 77.**

**Preheaters, air** (p. 78). Brochure from Air Preheater Corp. on "The Ljungstrom Air Preheater for Process Equipment." **Circle 23.**

**Processor** (p. 102). Technical info from Kontro on its centrifugally-wiped, thin-film processor. **Circle 17.**

**Pumps, canned** (p. 77). Composite Bulletin 1100 from Chempump Div., Fostoria Corp. **Circle 86.**

**Pumps, corrosion-resistant** (p. 27). In full range of sizes from 10 to 2,000 gal./min. Info in Bulletin 500 from Weinman Pump Mfg. **Circle 75.**

**Pumps, gear** (p. 129). Bulletin G-1 from Schutte and Koerting. **Circle 83.**

**Pumps, small, corrosion-resistant** (p. 111-112). Details from Eco Engineering on many types. **Circle 119.**

**Pumps, turbine** (p. 133). Technical Bulletin 105 from Roy E. Roth has complete mechanical data, performance curves on all sizes. **Circle 95.**

**Pyrometer** (p. 116). Bulletin 2146C from Alnor Instrument, Div. of Illinois Testing Labs, contains detailed specifications of Model 2300B. **Circle 24.**

**Rotameters, armored** (p. 134). Specially designed for hazardous fluids, high-pressure fluids, steam. Bulletin 19A from Schutte and Koerting. **Circle 84.**

**Scrubbers, fume** (p. 34). Technical data from Graham Mfg. on water-operated vacuum jet scrubbers. **Circle 48.**

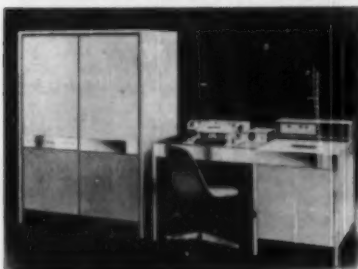
**Separation Equipment, solid-liquid** (p. 7). Technical info from Bird Machine on several types of centrifugals and filters. **Circle 76.**

**Studding Outlets** (p. 129). Available in all ASA standard sizes and pressures. General Catalog from Lenape Hydraulic Pressing and Forging Co. **Circle 82.**

**Tanks** (p. 124). Groban Supply Co. offers Catalog of fluid and gas pressure tanks, stainless and carbon steel tanks. **Circle 90.**

**Tanks, wood, polymer-lined** (p. 128). NWTI Bulletins 1 through 5 from Wend-nagel. **Circle 25.**

## DEVELOPMENT OF THE MONTH



### PROCESS CONTROL SYSTEM

(Circle 601 on Data Post Card)

An advanced process control digital computer system, the Libratrol-1000, capable of accepting data directly from analog instrumentation and of providing closed-loop operation has been developed by Librascope Div. of General Precision, Inc.

The new, completely transistorized system includes an advanced memory unit, new developments in read and write head design, and a built-in voltage-to-digital converter. These features are said to provide sufficient flexibility and versatility to fulfill the control requirements of the chemical, petroleum, steel, and atomic energy industries.

The computer is packaged for industrial environments and requires no external air conditioning. All computing elements, except the input-output devices, are sealed within an air-tight enclosure and a self-contained refrigeration system within the cabinet maintains temperatures conducive to maximum reliability and long life.

For more information, Circle 601 on Data Post Card.

**Tubing, reactor, aluminum** (p. 97). Info from Chicago Metallizing on internally aluminized reactor tubing. Circle 19.

**Tubing Bundles** (p. 133). Bulletin PPI-59 from Pyramid Plastics gives details of "Instrupack" polyethylene tubes enclosed in virgin PVC (vinyl) sheath. Circle 32.

**Vacuum Cleaner, industrial** (p. 84). Speeds catalyst change, furnace cleaning, etc. Info from Spencer Turbine. Bulletin 155B. Circle 72-1.

**Valves, plug, non-lubricated** (p. IFC). In many alloys, flanged or screwed, sizes from 1/2 to 6 in., 2- or 3-way design, 150 and 300 lb./sq. in. ratings. Bulletin V/4b from Duriron. Circle 49.

**Valves, safety-relief** (p. 121). New design plus Pyrex and Teflon construction gives full visibility, corrosion resistance. Bulletin RV-1 from Chem Flow. Circle 42-1.

**Viscometers** (p. 101). Accurate measurement, evaluation, and control of viscosity in any fluid. Details from Brookfield Engineering Laboratories. Circle 1.

**Weighers, continuous** (p. 32). Complete technical info in Bulletin 958 from Stephens-Adamson. Circle 29-3.

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For more information, turn to Data Service card, circle No. 33





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Send for Catalog I



For more information, Circle No. 34

## SUBJECT GUIDE

### to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

#### EQUIPMENT

**301 Centrifuge.** A 16-page Catalog from Lourdes Instrument Corp. contains full line of centrifuges and homogenizers.

**302 Chromatograph, gas.** Information describing chromatograph using tape programming to obtain greater precision in process control offered by Mine Safety Appliances Co.

**303 Chromatograph, gas.** Details from Loe Eng. Co. describes new programmed-temperature gas chromatograph.

**304 Combustion Safeguards.** Bulletin CS-2 from Selas Corp. of America presents improved line of automatic fire-checks and a new safety blowout design.

**305 Compressor, single-stage.** New Bulletin with six-step performance calculation method for selecting compressors from Elliott Co.

**306 Computer, analog.** Complete data on C4A/2 analog computer used in process control available from Swartwout Div. of Crane Co.

**307 Condensers, water-cooled.** Bulletin WC-300 on mechanically cleanable water cooled condensers for refrigeration and air conditioning from Halstead & Mitchell Co.

**308 Conveying Systems.** A 16-page Bulletin describes conveying systems from The Day Co.

**309 Cyclone Classifiers, liquid.** An 8-page Brochure from Dorr-Oliver Inc. describes rubber-lined liquid cyclone classifiers.

**310 Detector, overheat.** Bulletin from Walter Kidde & Co., Inc. describes overheat detector system.

**311 Disc Filters.** Bulletin 404 presents features for "FEinc" continuous vacuum disc filter from Filtration Eng. Div. of American Machine and Metals, Inc.

**312 Distillation Equipment.** Bulletin 3-1 from Consolidated Vacuum Corporation describes high-vacuum distillation equipment.

**314 Equipment, heat transfer.** A 32-page Catalog from Young Radiator Co. covers heat transfer equipment and contains facilities and services of company.

**315 Equipment, high pressure.** Bulletin 555-A describes 30,000 lb./sq. in. valves and fittings and Bulletin 160 describes a self-barricaded high pressure laboratory unit from Autoclave Engineers Sales Corp.

*continued on page 100*

#### MATERIALS

**357 Acetone.** A 12-page Booklet from Hercules Powder Co. contains information on acetone.

**358 Alloys.** A 20-page Bulletin containing alloy specifications is available from Ampco Metal, Inc.

**359 Alloy Steels, vacuum melted.** Data Book from Midvale-Heppenstall Co. gives properties of metals made by vacuum melting process.

**360 Anhydrous Formaldehyde Source.** Technical information for hexamethylenetetramine, Ucar hexa, which serves as a convenient, low-odor formaldehyde source. Union Carbide Chemicals Co.

**361 Chemicals.** A 12-page Booklet lists over 600 chemicals available from Aceto Chemical Co., Inc.

**362 Chemicals, wood by-product.** A 31-page Brochure from Marathon Div. of American Can Co. contains info on lignosulfonates.

**363 Coatings, vapor permeability tests.** Technical Bulletin from Wet Ground Mica Assoc., Inc. presents test data for pigmented organic coatings.

**364 Dielectric.** Information for organic film forming material called Cyanocel having high dielectric constant of 12.5 is available from American Cyanamid Co.

**365 Diesel Fuel Additive.** A 13-page Brochure from Oronite Chemical Co. describes OFA 265 additive for diesel fuel.

**366 Fatty Amines.** A 20-page Technical Manual "The Chemistry of Fatty Amines" is available from Armour Industrial Research Co.

**367 Metals, high purity.** New Brochure dealing with Space Age metals from The Lunex Co. contains properties of rare earth metals and yttrium.

**368 Metals, industrial.** A 14-page Brochure describes clad metals fabricated by Texas Instruments, Inc.

**369 Organic Chlorine Compounds.** A new 44-page Booklet from Union Carbide Chemicals Co. gives data and uses of organic chlorine compounds.

**370 Packings.** Catalog from Flexrock Co. gives applications for Teflon mechanical packings.

**371 Plasticizer.** Data Sheet from Hercules Powder Co. discusses polymeric, high-boiling, permanent plasticizer Hercoflex 900.



**372 Plastics.** A 64-page Catalog of plastic parts offered by Cadillac Plastic & Chemical Co.

**374 Radioisotopes.** A 15-page Booklet from New England Nuclear Corp. contains price list of labeled compounds.

**375 Rare Earths.** Data Sheets on catalytic properties of rare earths offered by Vitro Chemical Co.

**376 Resin.** Alkali soluble. Bulletin from Reichhold Chemicals, Inc. describes alkali soluble resin 1582 Waterez.

**377 Rubber,** fluorosilicone. Brochure from Dow Corning Corp. contains facts on Silastic LS solvent resistant silicone rubber.

**378 Stainless Steel,** manufacturing. A new 12-page Bulletin from G. O. Carlson, Inc. describes production of products from stainless steel.

**379 Silicone Antifoamers.** Booklet on silicone antifoamers for fast foam control is available from Dow Corning Corp.

## SERVICES

**380 Corrosion Data Charts.** Corrosive effects of almost 400 materials on 16 types of metals shown in charts from Nooter Corp.

**381 Data micro-reproduction.** A 6-page Folder from Minnesota Mining and Mfg. Co. discusses standards and specifications of Defense Department's data system.

**382 Engineering Data.** New 20-page Manual containing pumping and hydraulic data available from Peerless Pump-Hydrodynamics Division (FMC).

**383 Fabrication, equipment.** Brochure outlines capabilities of Ryan Industries, Inc. in custom fabrication and cryogenic equipment.

**384 Maintenance Painting Guide.** A 24-page guide to maintenance painting of industrial plants and equipment is available from Sherwin-Williams Co.

**385 Phosphate Rock, smelting.** Technical Bulletin from Tennessee Valley Authority shows effects of substituting coal for coke in electrical smelting of phosphate rock.

**387 Polishing, glass and plastic.** An 8-page Brochure from Vitro Chemical Co. contains technical information on rare earth glass polishing.

**388 Sensing Elements, mounting.** Bulletin entitled "Mounting Sensing Elements" from Norton Co. describes methods of mounting temperature and strain measuring elements using Rokide ceramic spray coatings.

**390 X-ray Bibliography.** A 20-page list of references covering 376 articles on X-ray analysis is available from Philips Electronic Instruments.

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The experience of our engineers over a long span of time has developed many highly productive, highly successful and highly profitable leaf filter designs constructed with a variety of materials to handle hydrochloric, sulfuric, fumaric and other mineral or organic acids. These feature tank linings of Hypalon, butyl rubber, plastisol and vinyl coatings to name a few materials currently being used for these strong acids. Leaf designs include materials of zirconium, titanium, polypropylene and PVC which have been proven for these services. Quick/Change polypropylene bags are common to most installations of this type and facilitate installation on leaf frames without operator sewing. Style of installation gives full security and tight surfaces which improve sluicing cake discharge economy. Additional features such as the efficient Rotary-Sluice, Reslurry Air Ring, Filtrate "Policeman" protective assemblies and Spacers are produced in this same variety of materials. Basic Vertical and Horizontal Tank Leaf Filters are available in these materials and are much less expensive than you may think.

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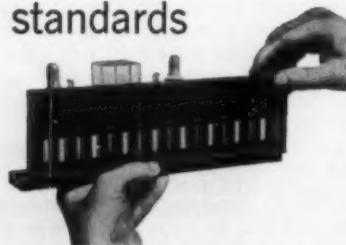
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For more information, Circle No. 96

## CEP'S DATA SERVICE—

Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

### EQUIPMENT from page 98

**316 Equipment, hydraulic.** New 74-page Catalog from Vickers Inc., Div. of Sperry Rand Corp., gives complete line of hydraulic products.

**317 Equipment, liquid processing.** New 24-page Catalog from Alsop Eng. Corp. describes line of filters, pumps, sealed discs.

**318 Equipment, materials handling.** A 32-page Booklet describes systems for handling bulk materials from Tote Systems, Inc.

**319 Equipment, materials handling.** A 24-page Catalog from B. F. Gump Co. presents line of equipment for process industries.

**320 Equipment, materials handling.** A 24-page Catalog from Sauerman Bros. Inc., provides info on storage and reclamation of bulk materials by Drag Scraper Machines.

**321 Gage, magnetic.** New 6-page Catalog from Jerguson Gage & Valve Co. gives complete details for magnetic gages used to measure liquid levels.

**322 Gravimeter, continuous recording.** Details from Central Scientific Co. describe on-line specific gravity measurements in 19-page Booklet.

**324 Homogenizers, ultrasonic.** A Guide to the techniques and applications of ultrasonic homogenizers is available from Sonic Eng. Corp. in Bulletin 160.

**326 Indicator, toxic vapors.** Description, applications for new aromatic hydrocarbon indicator from Johnson-Williams, Inc.

**327 Indicator-Controller.** Bulletin from Industrial Instruments Inc. presents features of electrolytic conductivity indicator-controller.

**328 Instruments, process.** Pressure gauges, thermometers, and control instruments are described in Bulletin 3020 from U. S. Gauge, Div. of American Machine and Metals, Inc.

**329 Ion Exchange, anion.** An 8-page Brochure from Ionac Chemical Corp. contains information on anion exchangers.

**331 Meter, low flow.** Bulletin describing meter for measurement of low flows available from Fischer & Porter Co.

**332 Mixers.** Bulletin B-522 describes RE series closed tank mixers and Bulletin B-523 covers open tank line of mixers from Mixing Equipment Co., Inc.

**333 Packings, gaskets, and seals.** Catalog from The Garlock Packing Co. describes static and dynamic sealing; also contains table showing effects of common media on packing materials.

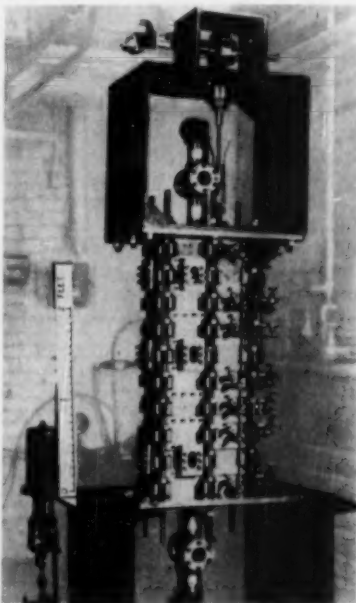
**336 Pressure Vessel.** Information for high capacity pressure vessel with patented aeration mechanism for complete removal of material from Systems Eng. and Mfg. Co.

**337 Processors, horizontal-tapered.** Bulletin from Kontro Co., Inc. discusses advantages of tapered units over straight-sided vertical units in thin-film processing machinery.

**339 Pulverizers.** Information from Pallmann Pulverizers Co., Inc. describes complete line of pulverizers and granulators.

**340 Pump, dielectric cooling.** Information for a dielectric cooling pump designed to operate submerged in fluorochemical fluids is available from Eastern Industries, Inc.

### DEVELOPMENT OF THE MONTH



### MULTISTAGE EXTRACTOR (Circle 602 on Data Post Card)

A multistage mixer-settler extractor for pilot plant solution of complex extraction problems and for limited scale production is being manufactured by the Pennsylvania Tool & Mfg. Co.

The assembled 20-stage extractor, shown above, consists of ten two-stage extractor decks with an interstage heating-cooling plate between each. Features of this unit are: feed rates to 2 gal./hr., stage efficiencies of over 98%, and provisions for sampling both phases and introduction of feed on each plate. A brochure containing a technical reprint from CEP completely describes the unit.

For more information, Circle 602 on Data Post Card.

**341 Pump Drives.** Bulletin PD760 from Eco Eng. Co. describes pump drives and accessories.

**342 Pump,** liquid proportioning. Information from Blackmer Pump Co. is available for the Vari-Flo vane-type positive displacement pump.

**343 Pump Motors.** A Brochure containing technical articles on pump motors is available from U.S. Electrical Motors, Inc.

**344 Pump, LOX.** Detailed specifications for light-weight, high-pressure pump for liquefied gases from Paul Chemical Co., Inc.

**345 Pumps,** reciprocating. Data Sheet 100 gives complete information for 25 to 2400 h.p. direct flow pumps from Aldrich Pump Co.

**346 Pumps,** self-priming. Information from Ingersoll-Rand describes efficient, self-priming centrifugal pump for petroleum products handling.

**347 Pump,** submersed gear. Information concerning pump from Eco Eng. Co. mounted below reactor cover plate with motor drive mounted above.

**348 Pyrometer Accessories.** A 55-page buyers' Guide and users' Manual for thermocouples and pyrometer accessories from The Bristol Co.

**349 Radiation Meters.** Information for the Model L-64 roentgen meter for measuring X-rays and gamma rays available in Booklet from The Landsverk Electrometer Co.

**350 Regulator,** stainless steel. Bulletin from Thermco Instrument Corp. describes pressure regulator for sampling compressed gas.

**351 Regulators,** gas. A 16-page Catalog from Linde Co. describes industrial gas regulators and portable manifolds.

**352 Screw Conveyor Drives.** New Folder from Link-Belt Co. gives selection data for screw conveyor drives.

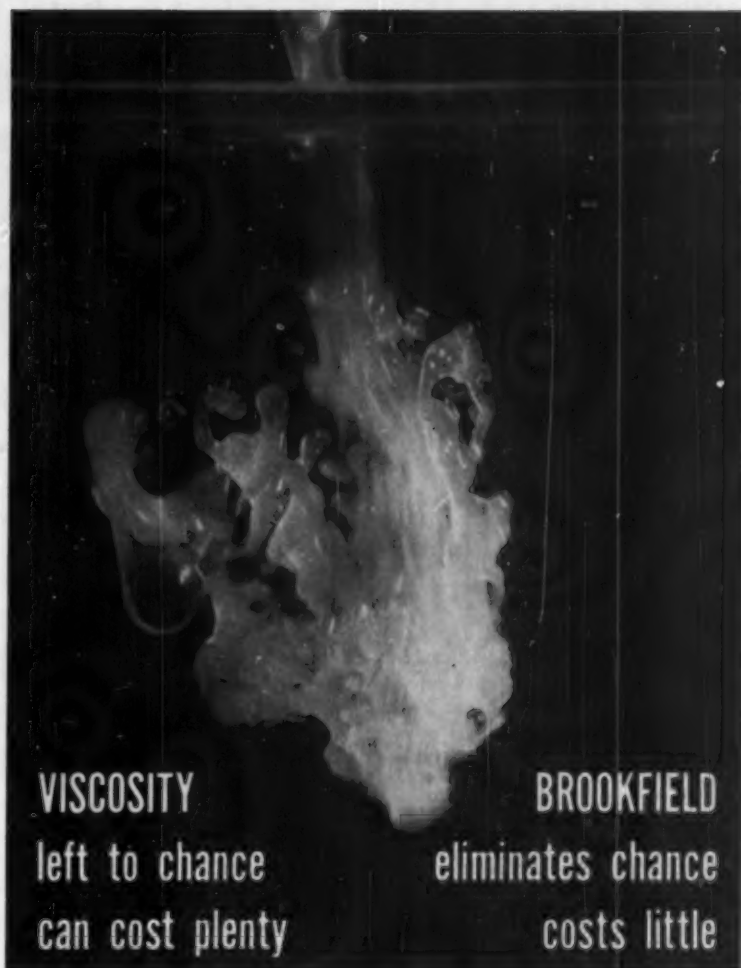
**353 Seals,** rotating shaft. New 32-page Catalog describes basic seal designs available from Cartriseal Corp.

**354 Traps,** steam. Condensed 1960 Catalog from Sarco Co., Inc. contains line of traps, regulators, heating specialties.

**355 Valve,** pressure reducing. Information from OPW-Jordan describes new pressure reducing valve with capacity of 50,000 lb. steam per hour.

#### A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 600 on Data Post Card.



**VISCOSITY**  
left to chance  
can cost plenty

**BROOKFIELD**  
eliminates chance  
costs little

If you, like most chemical processors, are in the rough marketing position whereby you can't tolerate needless production waste . . . then give this some thought.

Have you considered the role of viscosity control in your processes? If not — you should! Viscosity is a product dimension that experience has shown should not be ignored . . . a product dimension Brookfield has proved need not be ignored. Both Brookfield laboratory Synchro-Lectric Viscometers and process-mounted Viscometrans involve small investments; yet they provide easy, accurate measurement, evaluation and control of viscosity in any fluid. Brookfield instrumentation is so simple that no special personnel training is required for operation.

Complete information, specific to your particular problems, if you wish, is available without obligation. Write today.

THE WORLD'S STANDARD FOR VISCOSITY  
MEASUREMENT AND CONTROL



**Brookfield**

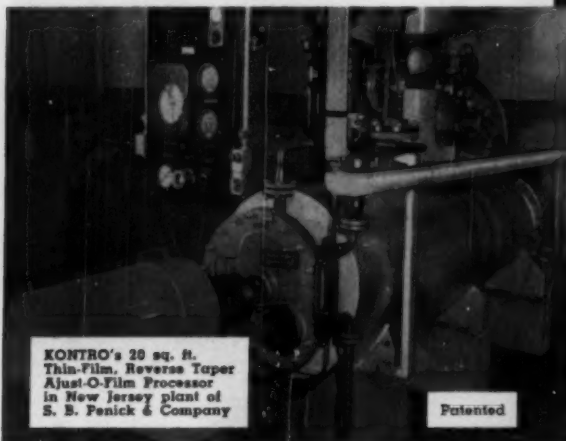
ENGINEERING LABORATORIES, INCORPORATED  
STOUGHTON 18, MASSACHUSETTS

For more information, turn to Data Service card, circle No. 1



# PENICK Produces Superior Medicinal Chemicals With KONTRO Equipment

S. B. Penick & Company, experienced manufacturer of fine chemicals for the pharmaceutical industry, requires specialized and diverse equipment for a variety of products. The KONTRO Processor fills this need through its extreme versatility in handling a number of different materials, each involving a separate processing problem.



The KONTRO Processor operates on the centrifugally-wiped, thin-film principle. The tapered wall of the processing section—an exclusive feature—allows complete control of the process through adjustment of the rotor and the blade-clearance within the heat transfer wall.

- Concentration to high degree . . . or development of moderate viscosity from thin feed
- Processing of ultra-heat-sensitive materials
- Operates under high vacuum
- Easily cleaned through hand holes, in order to accommodate different materials one after another without contamination
- Reverse Taper design prevents dry spots and "burning on", . . . irrespective of degree of concentration
- Simple, compact, one-floor installation

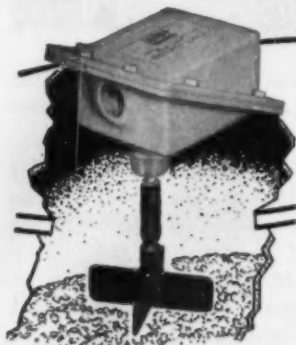
## KONTRO

The Kontro Company, Inc. PETERSHAM • MASSACHUSETTS

In Europe, Samesreuther & Co., G.M.B.H., Butzbach, Hessen, Germany

## NEW MATERIAL LEVEL UNIT HAS FAIL-SAFE FEATURE

- Detects
- Indicates
- Controls



For

- BINS
- HOPPERS
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**Flo-Level  
Model L-400**

The Flo-Tronics Flo-Level Model 400 is a new electronic self-contained device that automatically detects, indicates or controls powdered or granular material levels at selected points in your system. Rotating paddle generates signal which operates indicating or controlling equipment. If power or any portion of unit fails, the control contacts immediately act to provide high-level or low-level fail safe operation, as desired.

The Flo-Level Model L-400 is compact, rugged, weatherproof and explosion-proof.

**FREE CATALOG** with application data will be mailed to you on request by writing to



**FLO-TRONICS, INC.**

Electronic Control Division  
1420 Zarthan Avenue  
MINNEAPOLIS 16, MINNESOTA

For more information, turn to Data Service card, circle No. 20

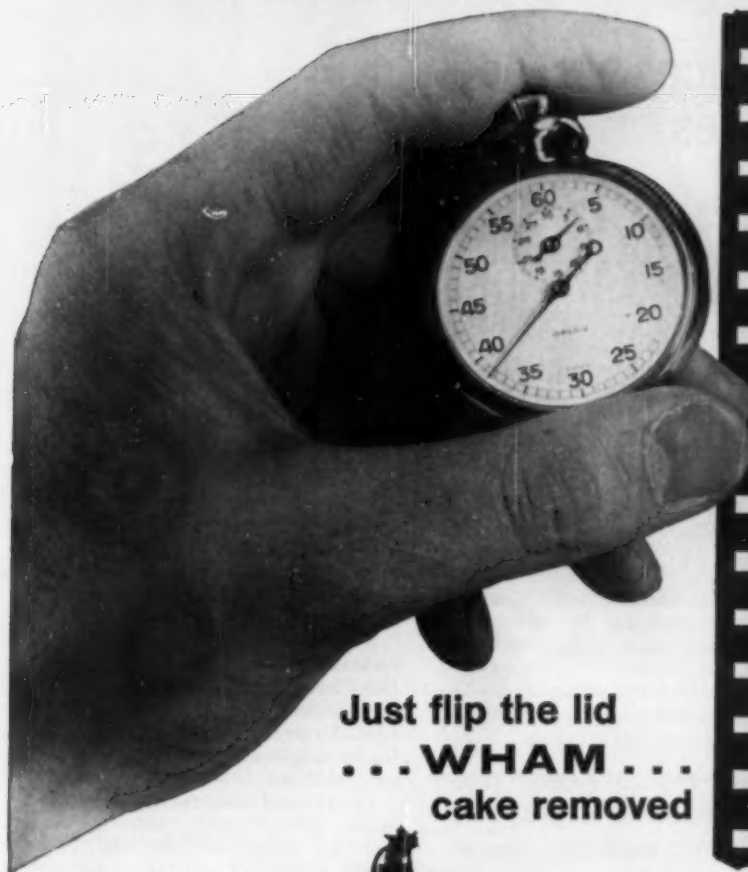
### IMPORTANT NOTICE

If your address has changed, please fill out this form and mail to Chemical Engineering Progress, 25 West 45th Street, New York 36, New York.

EFFECTIVE DATE OF NEW ADDRESS		DATE OF THIS NOTICE	
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# SAVE TIME and EFFORT WITH MODERN FILTERS

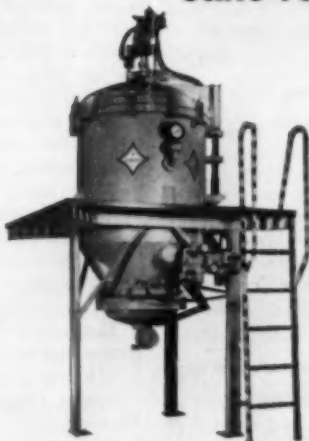


Just flip the lid  
... **WHAM** ...  
cake removed



CP-28

These rapid cleaning devices on INDUSTRIAL filters offer tremendous advantages to the user through removal of, and subsequent disposing of waste materials or recovery of valuable solids.



For additional information  
write for Bulletin EP-100.

**INDUSTRIAL**

**INDUSTRIAL FILTER & PUMP MFG. CO.**

5910 West Ogden Avenue, Chicago 50, Illinois

With VIBRA-SHOC or RECIPRO-SHOC, cleaning of your INDUSTRIAL filter is completed in minutes. The above mentioned trade named devices are obtainable on INDUSTRIAL'S TYPE 152 filters, as are such optional equipment as QUICK OPENING COVERS, LIQUID SHOC and AIR WASH, all designed with the efficiency you require for your particular operation. All these mechanical aids work for you to realize a definite cost savings based on reduced downtime, for either continuous or batch type operation. These self-cleaning devices also eliminate the manual dirty work in handling any dry, wet or semi-solid material.

PRESSURE FILTERS • ION EXCHANGERS • CORROSION TEST CABINETS • PUMPS • WATER & WASTE-TREATING EQUIPMENT

For more information, turn to Data Service card, circle No. 6

CHEMICAL ENGINEERING PROGRESS, (Vol. 56, No. 10)

October 1960

103

## General Electric places its bets on polycarbonate resins

**\$11 million is riding on new thermoplastic polymers as GE opens 5 million lb./year plant in Indiana to begin full-scale commercial production.**

POLYCARBONATE RESINS have received an \$11 million vote-of-confidence from General Electric Co. This is the amount spent by the company's Chemicals Materials Dept. to date, and includes research and development costs plus a brand-new plant at Mt. Vernon, Indiana, with an immediate capacity of more than 5 million pounds per year. This capacity can be upped to more than 11 million pounds per year without any increase in physical facilities, according to Dr. A. E. Schubert, general manager of the department. Conceivably, this would be done by changes in operating conditions and rates already proved out in semi-works equipment. Plant layout also provides for later doubling of facilities simply by adding "mirror images".

GE is betting on polycarbonates to develop an annual market potential of 30-50 million pounds by 1965, and to be in the 75-100 million pound range within 10 years. Coupled with this is a price decline which will find the materials selling between 60 and 85¢ a pound within five years. The resin was introduced at \$2.50 a pound in 1957, and now sells for \$1.50 a pound.

Polycarbonates are polymers with carbonate forming the link to aromatic

groups. The Lexan resin, which GE is making commercially, is obtained by reacting phosgene with bisphenol-A. Hydrochloric acid is split out from the phenol groups and the carbonyl chloride, and a linear polymer results. One of the big advantages of the polymers, and one on which high hopes have been placed, is their ability to be cross-linked with other groups added to form co-polymers. Work is underway to make a family of polycarbonates by adding such compounds as terephthalic acid, glycols, and polyesters.

Competition is strong in the marketplace, both from other plastics and from conventional materials. The poly-

**Polycarbonates: Price and Volume Forecast.**

YEAR	PRICE \$/lb.	TOTAL Market Million lbs./yr.
1957	2.50	—
1960	1.50	—
1962	0.9-1.2	6-12
1965	0.6-0.85	30-50
1970	0.6-0.85	75-100

carbonates aim to match the competition through a combination of properties which make the resins able to withstand fairly severe conditions. The GE material is highly ductile thermo-

plastic, which means it can be fabricated by such conventional methods as injection molding, extrusion, blow molding, vacuum forming, and cold forming. Meanwhile, its high impact strength makes it comparable to thermosetting materials reinforced with glass fibers. It can be drawn, forged, and stamped like metal, and in some aspects approaches the strength of metal.

Properties which make it especially attractive are:

**Impact strength.** A high impact resistance means that articles fabricated from the resin can be dropped, or accidentally jarred, without damage. This makes the material desirable for housing equipment, such as business machines.

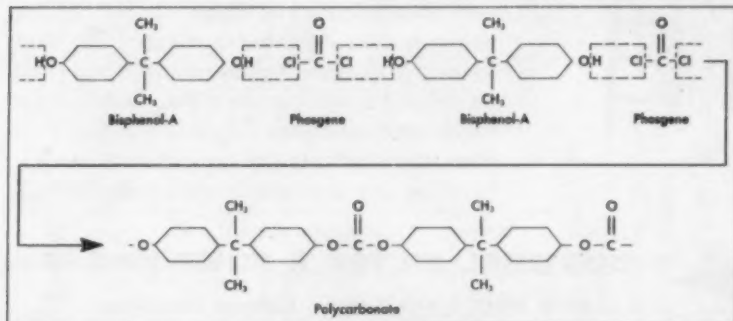
**Dimensional stability.** High temperatures, sudden loading, water immersion, and impact have little effect due to this stability. This is important for use in high-precision molded parts and film products.

**Creep resistance.** It retains its shape within one mil per inch under moderate loadings and temperatures. Expansion and contraction within this proportion occurs with each 26°F temperature change. Static loads must be kept from exceeding a 1,500-2,000 lb./sq.in. range to avoid distortion.

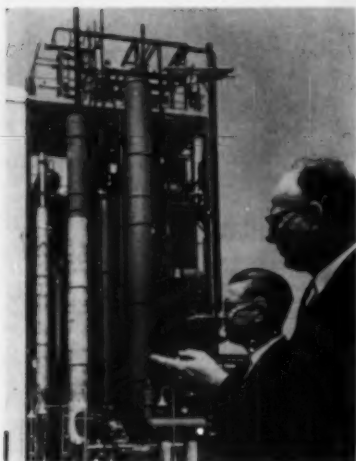
**Thermal stability.** Low and high temperatures within a -60°F to 270°F range have no effect on strength. This exceeds military specifications.

**Non-corrosive.** There are no additives required to prepare the resin for use. The virgin material is non-corrosive.

**Self extinguishing.** No chlorinated additives are necessary to make the resin self extinguishing. This inherent property makes it desirable in itself, and also cuts down the introduction of possible corrodents.



Reaction for the production of GE's new polycarbonate resin.



Dr. George McCullough, Manager, polycarbonate manufacturing, and Dr. A. E. Schubert, General Manager, chemical materials department, inspect GE's new polycarbonate resin plant just prior to startup.

The plastic also has good electrical properties, high machinability, is stain resistant, and accepts pigments or coatings to provide high gloss finishes.

The Mt. Vernon plant is to serve as the center of GE's expanding Chemicals Materials Dept. Present plans call for future plants to be constructed here, with the possibility of shifting the main office to the locality. The plant was designed and engineered by Crawford and Russell, Inc., Stamford, Conn.

A contact sulfuric acid plant at Brewster, Fla. will be engineered for American Cyanamid by Leonard Construction is slated for completion by mid-1961.

Resins for use in the surface coating, adhesive, bonding, laminating and polyester industries of Uruguay will be manufactured by Reichhold Chemicals. The company recently signed a license agreement with Compania BAO, S.A. Montevideo.

Commercial production of triphenyl phosphite, diphenyldecyl phosphite, phenyldidecyl phosphite and tridecyl phosphite has started at full scale at Hooker Chemical. The organophosphites are being produced at recently completed facilities at the company's Niagara Falls plant.

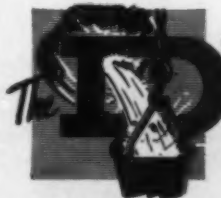
Commercial production has begun of parachlorothiophenol at the Henderson, Nevada plant of Stauffer Chemical. Major uses are expected in the fields of oil additives manufacture, agricultural chemicals, plasticizers, rubber chemicals, dyes, wetting agents and stabilizers.

# DURALOY

## 25-20 Casting with Welded Assembly

This is a separator destined for a reaction process. It is typical of the kind of work we do in the high alloy casting field. In the 25 Cr-20 Ni range it is alloyed to withstand both corrosion and heat. Assembled, its weight runs some 2000 pounds. It was inspected and tested under very rigid ASME Code requirements.

The production of chrome iron and chrome nickel castings has been our sole business since 1922. We added centrifugal castings to our service in 1933 and shell molded castings in 1955. Our metallurgists have extensive knowledge of the many operations requiring high temperature and corrosion resistant castings. Perhaps this experience would be helpful to you if you are confronted with a specific problem and wish to determine the best alloying combination for your required castings. We can be helpful, too, in designing the unit, contributing our knowledge of strength and stresses in castings.



# DURALOY Company

OFFICE AND PLANT: Scottsdale, Pa.

EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.

CHICAGO OFFICE: 332 South Michigan Avenue

DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.

For more information, turn to Data Service card, circle No. 14



## Highly Intimate Blends in 1 to 2 Minutes

**Blends while discharging;  
No segregation or flotation**

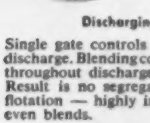
Sturtevant Rotary Blenders start 4-way blending while charging, continue it during discharge, thus producing highly intimate, even blends of dry and semi-dry materials — within 3 to 5 minutes of start of charging.

Six complete blending cycles per hour are common. And Sturtevant's special action produces no particle reduction, cleavage or attritional heat — is highly effective yet gentle and safe even with explosives.



Receiving

Scoops cascade material as drum rotates. Movement forces material from both ends to middle. Thus blending is 4-way right from start of charging.



Discharging

Single gate controls charge, discharge. Blending continues throughout discharge phase. Result is no segregation or flotation — highly intimate, even blends.

**Self-cleaning, dust-sealed drum;  
one-man accessibility**

Operation of Sturtevant Blenders is self-cleaning — drum interiors are completely dust-sealed. For inspection of all models, one man simply loosens a few lugs to remove manhole cover — quickly and easily.

**Nine standard models with  
capacities to 900 cu. ft.**



10 cu. ft. Sturtevant Blender at U.S. Steel Corp.'s new Applied Research Laboratory (Raw Materials Division) in Monroeville, Pa. This unit handles batches up to 500 lbs. — is ideal for pilot work and small runs.



One of four 450 cu. ft. Sturtevant Blenders at Celtrivier Plant of Celanese Corp. (Rock Hill, N. C.). These large units handle up to 20,000 lbs. batches — have a 9-year record of meeting the most exacting blending requirements.

**Fully or semi-automatic, or  
manually controlled operation**

Constructed of carbon steel, stainless steel or Monel metal, Sturtevant Rotary Blenders are engineered to fit each customer's needs — can be supplied with injector sprays and any desired control system.

For more on Sturtevant Blenders, request Bulletin No. 080B. (Bulletins also available on Mixers, Air Separators, Micronizers, Crushers and Grinders.) Write today. STURTEVANT MILL CO., 135 Clayton St., Boston, Mass.

For more information, circle No. 28

## industrial news

**Humble, Monterey Oil,  
talk merger**

**Negotiations on for Humble Oil to  
take over Monterey assets; would  
add \$100 million to Humble in  
one of biggest oil mergers in  
years.**

RECENT CONFIRMATION of the reported negotiations between Humble Oil & Refining and Monterey Oil Company came as no surprise to trade circles. Talks looking toward acquisition of the assets of Monterey by Humble have been rumored for some time. If an agreement does come about, it would be the biggest oil merger in years, joining the \$3 billion assets of Humble, Standard Oil N. J. domestic affiliate, to Monterey's \$100 million. For the past year, Monterey has been reported up for sale if the price is right.

Humble is one of the nation's biggest oil producers. Late last year, Humble and Jersey Standard stockholders approved a plan under which Jersey acquired all Humble shares and Humble itself was expanded to include all the domestic Jersey operations. This was part of a bigger plan under which the new company's operations would extend over the entire United States.

The new Humble organization has about one-tenth of the nation's crude oil and natural gas liquid reserves. Production amounting to about 450,000 barrels daily at the end of 1959, centered largely in Texas, but takes in most of the major oil producing states. Monterey is an independent producer from fields in California, Texas, Wyoming, New Mexico, Oklahoma and Louisiana. Its crude and natural gas reserves are estimated at about 68 million barrels, as against an estimated 3,600,000,000 for Humble. The Humble organization markets oil in forty states.

The industry will be watching to see how the Justice Department reacts to the merger, if and when it is completed. Some oil men believe the trend toward mergers is so strong that some legal test will result. #

**A 50 percent expansion in oxo-alcohol  
capacity has been completed at Enjay  
Chemical Baton Rouge refinery. This  
brings total oxal capacity at the plant  
to 90 million pounds a year.**

... one of a series presented by Western Supply Company, Tulsa, to improve the "I.Q." of engineers ... ("Income Quotient")

## Design Economics of Heat Exchangers Furnish Basis for Heat Transfer Cost Engineering

The application of cost engineering practices in the accurate evaluation of capital equipment in the process industries is rapidly becoming more and more vital to the management of process companies, as margins of profit grow narrower.

Management now depends increasingly, therefore, on modern cost-engineering practices to evaluate realistically the true, long-range economy of a given piece of equipment in relation to its initial cost, cost of installation, maintenance, operation, labor, replacement — and in relation to the productivity or profit of the process involved.

The importance of efficient, practical, long-range forecasting is increasingly a focal point in the process industries as a whole, but no where is it more important than in the purchase and operation of heat exchangers for use in continuous flow processes, where the operation of the unit never ceases, and therefore must be calculated on a basis of maximum longevity, efficiency and service. Included in the design of each heat exchanger must be a consideration of its initial cost, its cost of installation (including piping, fittings, valves, flanges, etc.), its operation and maintenance (including corrosion-protection, mechanical maintenance, cleaning, re-tubing, replacement parts) — and the factor of labor costs attendant to the installation, operation, maintenance and/or replacement of the unit.

In each case, however, the basic factors must be considered and determined: capital, overhead, maintenance and unit process costs.

The Cost Engineer, therefore, must be committed to continual study, re-examination and reevaluation of every area which contributes to the practice of chemical engineering, for it is from his fundamental and technical knowledge of the process involved that his eventual forecasts for productivity, efficiency and longevity must ultimately spring.

Considerable thought has been given to the "ideal" background or qualifications for the Cost Engineer. Certainly his primary requisite must be thorough knowledge of chemical engineering, including, in the heat transfer field, an equally intimate grasp of the thermal and metallurgical engineering so vital to an understanding of heat exchanger design economics.

Secondly, he should have had practical experience in the production phases of the chemical business. Thirdly, he will be better equipped to understand the complexities of the "business" side of such evaluations, if he has had education and/or experience in a certain amount of business administration.

Clear, concise, understandable communications is another factor of great importance to the ultimate success of the Cost Engineer, for he must transmit his findings, make his recommendations and defend his decisions to a number of widely varied types of people, some with technical background and others with little or no technical knowledge.

The Cost Engineer must be tireless on detail, inquisitive at each point, yet tactful in his demands on subordinates and associates. Above all, although cost engineering presents a real challenge to the analytical mind, he must serve his purpose with genuine humility, cognizant of the amount he has yet to learn.

In short, he should have a proclivity towards the functions of management, for that is where he might very well be headed.

(FOOTNOTE: For more detailed information on this subject, write for your free copy of "Cost Engineering" to WESTERN SUPPLY COMPANY, HEAT EXCHANGER DIVISION, P. O. BOX 1888, TULSA, OKLA. — and for immediate assistance on heat transfer cost engineering, feel free to suggest our services — whether or not there's a heat exchanger in your company's future!

For more information, circle No. 123



# 13 COOPERATING COMPANIES\* SELECT GENERAL AMERICAN RDC COLUMN FOR PROTOTYPE PLANT

Lignite low temperature tar is a relatively new and unknown raw material. To determine its potential value, a cooperative research program was started by 13 companies in 1954 at the Battelle Memorial Institute.

One of the important developments has been a solvent extraction process . . . a countercurrent extraction of this tar with 75% methanol—25% water and commercial hexane . . . using the RDC column. The development appeared so promising that a prototype plant was constructed at Alcoa's Rockdale Works by Texas Power & Light Company incorporating a General American RDC pilot column. *Only* the RDC column combines all these advantages: High volumetric efficiency, high throughput capacity, elimination of inter-stage settling, flexibility for changing feed conditions, lower power requirements, simple construction, tolerance for solids.

For any applications dealing with liquid-liquid, liquid-solid, liquid-slurry extraction . . . why not get full information on a General American RDC column? (Write for Bulletin #T-1159) Remember, *it pays to plan with General American.*

Process Equipment Division—Turbo-Mixers  
**GENERAL AMERICAN TRANSPORTATION CORPORATION**

135 South LaSalle Street  
Chicago 3, Illinois  
Offices in principal cities



\*Names on request

EXCLUSIVE RDC LICENSEE IN THE PROCESS INDUSTRY

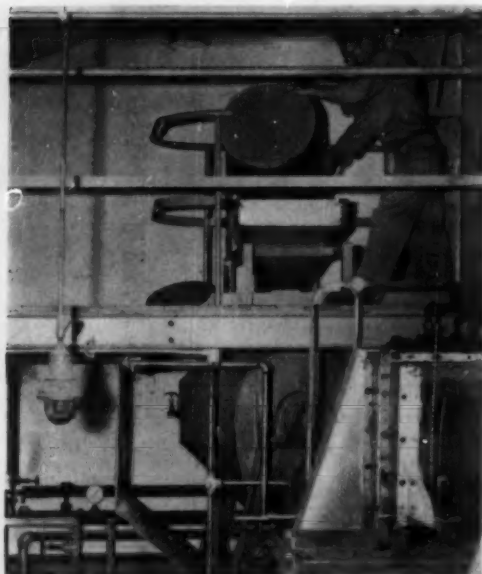
TRADE MARK



For more information, turn to Data Service card, circle No. 116

# PAUL O. ABBÉ ROTA-CONE DRYER

**"WE DRY AT LOWER TEMPERATURE  
AND MORE EVENLY WITH  
PAUL O. ABBÉ ROTA-CONE DRYER"**



"The tumbling action in drying our heat-sensitive materials in your 'Rota-Cone' Dryer assures us drying at lower temperatures and more evenly, since it gives contact of the material with the heated surface, and the vacuum removes the moisture-laden air," an important chemical manufacturer tells us.

"Incidentally, this tumbling action produces a more uniform product by providing a mixing action at the same time that it dries the material."

The concern using this dryer also reports other advantages over tray drying: Less exposure to dirt, less space, and 1/3 less labor required. Temperatures automatically controlled from 30° Centigrade to 90° Centigrade.

The "Rota-Cone" Dryer is used for plastic resins, chemical powders in flake or granular form, textiles, pharmaceutical and metal powders.

Avoid higher labor costs, dirt, and decomposition of heat-sensitive materials. Switch to a Paul O. Abbé "Rota-Cone" Dryer—available in capacities from 1 to 500 cubic feet.

*For full details of this equipment, write today for our 12-page illustrated "Folder C — 'Rota-Cone' Blenders and Vacuum Dryers."*

**PAUL O. ABBÉ**  
271 CENTER AVE. LITTLE FALLS, NEW JERSEY

**BALL & PEBBLE MILLS  
DRY & PASTE MIXERS  
DRYERS & BLENDERS**

For more information, turn to Data Service card, circle No. 53

## industrial news

### Israel to get major citric acid plant

Haifa plant, to be on stream in 1961, will use Miles Chemical deep fermentation process.

HAIFA, ISRAEL, will be the site of a \$2 million citric acid plant to be built by Miles Chemical, division of Miles Laboratories, Elkhart, Indiana. The plant, slated for completion in late 1961, will use the Miles-developed "deep fermentation" process, now in commercial operation only in Miles' own Elkhart plant.

Annual capacity of the new plant will be 1,500 short tons, will put Israel among the world's largest citric acid producers—others are the U. S., England, Germany, Belgium, Holland. (Mexico will join the leaders in the near future when an almost completed plant of Quimica Mexama, also using the Miles process, goes on stream.

#### Aimed at export

Only half of the plant's projected output is scheduled for consumption within the state of Israel, while the other fifty percent will be marketed in the Near Eastern area. According to H. F. Roderick, Miles Chemical president, "our decision to build a citric acid plant was influenced by the attractive incentives offered by the Israeli government, the hot climate which is conducive to citric acid consumption through soft drinks, and the favorable trade relations Israel has established with twenty-two other nations which represents a strong export potential."

#### Investment climate

Announcement of the Miles citric acid venture marks another milestone in the attempt of the Israeli government to create an investment climate attractive to foreign capital. The "Law for the Encouragement of Capital Investments," first passed in 1950, and amended in 1955 and 1959, grants certain major tax reliefs and financing to projects believed likely to promote a favorable trade balance. In addition, it allows American investors to take all their profits out of the country in dollars.

The "all-Israeli" operation will be continued on page 110

For more information, circle No. 9



## **Kellogg Plant Engineering Goes to Work for SunOlin**

Now in operation at North Claymont, Delaware, SunOlin Chemical Company's new urea plant, below, is a working replica of the model shown above, which Kellogg built and used in engineering and erecting the project. Utilizing the Fauser-Montecatini Process, this plant is the first major urea plant on the East Coast—and produces over 200 tons per day of crystalline and prilled urea.

A major feature of the plant is the Kellogg-designed steam-methane reformer, which produces the 150 tons of  $\text{CO}_2$  required each day for reacting with 120 tons of  $\text{NH}_3$  to form the ammonium carbamate which is dehydrated to urea and water. Much of this water is used to absorb unreacted  $\text{NH}_3$  and  $\text{CO}_2$ . These reactants are then returned to the reactor for re-use.

Kellogg welcomes the opportunity to discuss its engineering-procurement-construction services with you, and to show you how its model techniques can expedite plant design and completion.

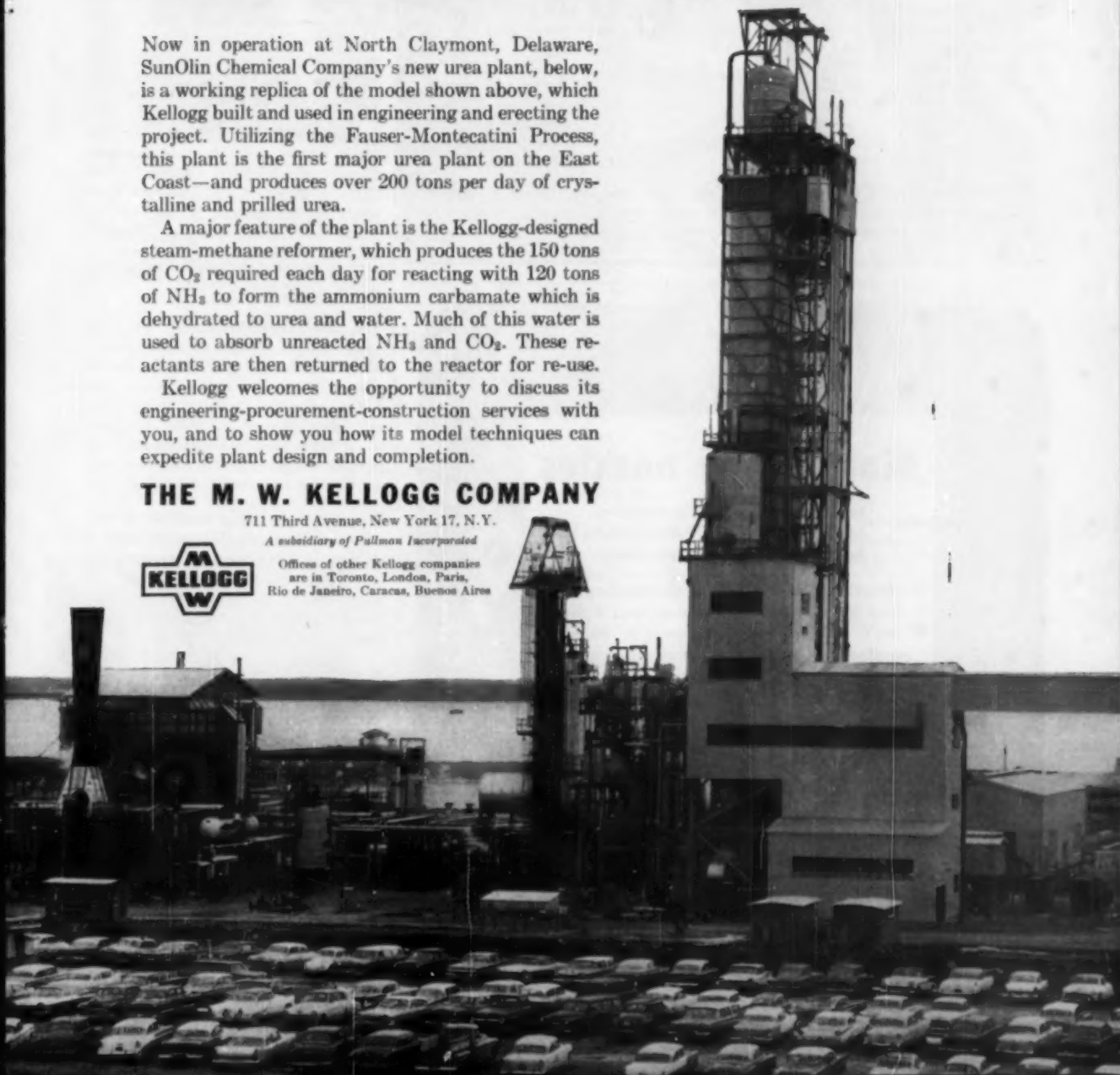
### **THE M. W. KELLOGG COMPANY**

711 Third Avenue, New York 17, N.Y.

*A subsidiary of Pullman Incorporated*



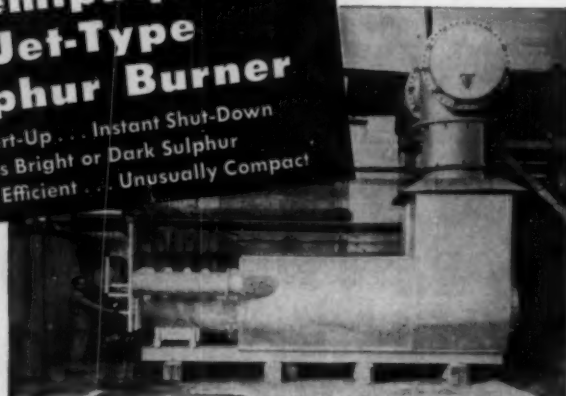
Offices of other Kellogg companies  
are in Toronto, London, Paris,  
Rio de Janeiro, Caracas, Buenos Aires



## Chemipulp-KC Jet-Type Sulphur Burner

- Fast Start-Up . . . Instant Shut-Down
- Handles Bright or Dark Sulphur
- Highly Efficient . . . Unusually Compact

30-ton installation,  
Rayonier Canada  
Limited, Port Alice,  
B. C.



In the Chemipulp-KC Burner, molten sulphur is sprayed into the burner as a fine mist; heated secondary air is then introduced in several stages, resulting in clean, efficient burning. The burner quickly reaches its operating temperature of about 2400°F., minimizing production of SO<sub>3</sub>. Operates efficiently at all SO<sub>2</sub> concentrations between 12%

and 18½%. At 2100°F., bitumen in dark sulphur is completely burned.

Available in a range of sizes up to 50 tons of sulphur per day and each size will produce SO<sub>2</sub> gas efficiently through a wide operating range. Compact design and flexibility of layout permit installation in limited space.

Write for Bulletin 100

**Chemipulp Process Inc.** Woolworth Building, Watertown, N.Y.

Associated with Chemipulp Process Ltd., 253 Ontario St., Kingston, Ontario

Pacific Coast: A. H. Lundberg, Inc., P. O. Box 186, Mercer Island, Wash.

Lundberg-Ahlen Equipment Ltd., 779 W. Broadway, Vancouver 10, B. C.

## Binks spray nozzles

for washing, cooling, processing,  
humidifying, dehydrating, and  
hundreds of other applications.

You'll get the right nozzles quicker by calling Binks...manufacturers of one of the most complete selections ever produced.

There is a size and spray pattern for every purpose...with nozzles cast or machined from standard or special corrosion-resistant metals and materials.

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A COMPLETE LINE OF  
INDUSTRIAL SPRAY NOZZLES  
AND COOLING TOWERS



**Binks Manufacturing Company**  
3114-32 Carroll Ave., Chicago 12, Ill.  
O. K. Binks, send me your comprehensive Spray Nozzle Catalog without obligation.

NAME \_\_\_\_\_  
COMPANY \_\_\_\_\_  
ADDRESS \_\_\_\_\_  
CITY \_\_\_\_\_ ZONE \_\_\_\_\_ STATE \_\_\_\_\_

## Citric acid

from page 108

controlled by Miles Chemicals Israel Ltd, newly-formed subsidiary of Miles Laboratories. Israeli technicians will be flown to Elkhart for an intensive three-month training course, after which Miles says it will back up the Israeli operation with "whatever technical assistance is needed during start-up and production."

Vinyl acetate monomer will be manufactured by Reichhold Chemicals under a license agreement between Wacker Chemie G.M.B.H., Munich, Germany, and the American firm. A 50 million pounds initial capacity plant, with planned expansion to 100 million pounds a year, will supply polyvinyl acetate emulsions to the paint, adhesive, textile and paper industries. Location, in the United States, is not yet chosen.

Development work on graphite for use in missile and space vehicles goes ahead, with National Carbon (Union Carbide) awarded a \$12 million, three year research contract by the U.S. Air Force R&D Command. An advanced material Laboratory will be built by Carbide at Lawrenceburg, Tenn., for this purpose.

The 300-ton-per-stream-day ammonia plant being designed near Joplin, Missouri, for Solar Nitrogen Chemicals, will use the Kellogg steam methane reforming process. Atlas Powder, joint owner of Solar Nitrogen along with Standard Oil (Ohio), will operate the plant. Sohio Chemical will market the anhydrous ammonia.

More organic sulfur facilities in the offing at Pennsalt Chemicals, with a variety of alkyl mercaptans planned for production in a new plant unit. Expansion of the company's Houston, Texas, facility is scheduled for completion early in 1961.

A new research center to be constructed by Texaco at its Port Arthur, Texas, refinery, will provide the company with a second major center. The 15 acre facility will carry on mostly pilot plant projects. Included are development and manufacture of new petrochemicals, more economical refining processes, composition and use of asphalt, corrosion and contamination problems. While Texaco's immediate purpose is to centralize its personnel, the move also means an expansion in its research facilities.



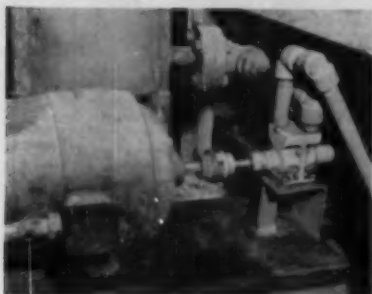
# ECO

## ENGINEERING

# NEWS

*the big name in small pumps for the process industries*

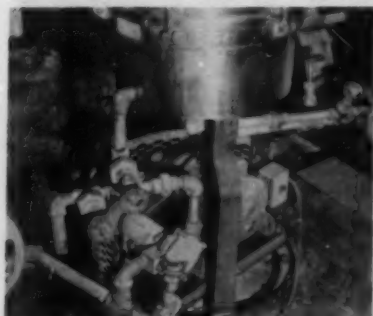
### Seven Years Hard Service Only Repair, Seal Replacement



True Brite Chemical Products Co., Oakville, Conn., producers of sodium and potassium copper cyanides and other essentials for metals finishing, are long-time users of Eco Pumps.

Their satisfaction stems from such performances as that of the Eco ALL-CHEM pump pictured above, pumping sulphates and dilute sulphuric acid to a rotary vacuum filter. In seven years of continuous intermittent service, the only attention required has been a replacement of the gland packing.

This 316 stainless steel pump has now been relieved by another Eco ALL-CHEM (True Brite keeps replacements on hand for each Eco pump in case of emergency need), while the old pump is being equipped with new Teflon interchangeable rotors and sleeve bearings, ready for another seven years of trouble-free service.



This Eco CENTRI-CHEM Pump at True Brite feeds sodium copper cyanide (double salts) to one of the dryers employed in this plant. All filters and dryers are Eco pump equipped and, according to President Henry Strow, they have been found to be the best pumps available for the services involved.

tdu Pont Trade mark



### Eco Pumps Protect Clarity, Color and Un-contaminated Purity of Pharmaceuticals

Pharmaceutical Industries, Inc., Merchantville, N. J., ship world-wide such products as Liposal for treating infantile eczema and asthma; Polymul, an infant fat modifier; and Donic for reducing cholesterol—a "heart-felt" blessing to many of us.

#### Employ Nitrogen Atmosphere

The preparation of these pharmaceuticals requires extremely exacting processing, since they are made from highly unsaturated vegetable and marine oils which are very oxygen labile.

Processing is carried on in a nitrogen atmosphere of about 2 psi above normal atmosphere.

Both Eco ALL-CHEM Pumps and GEARCHEM Pumps of 316 stainless steel with Teflon trim and gland seals are used to handle the component materials and the finished products—which are packaged in transparent individual dispensules revealing color and clarity of dosage.

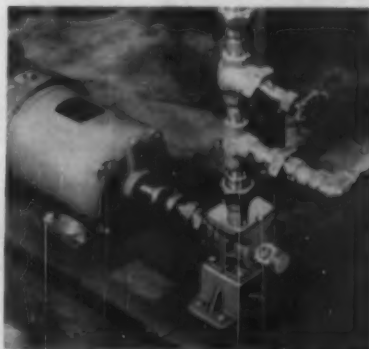
#### Four Years "Uneventful" Service

The two Eco ALL-CHEM Pumps, illustrated above, have handled more than a quarter million gallons of oxygen labile pharmaceuticals during the past 4 years of uneventful continuous service.

#### Pumps Very Satisfactory

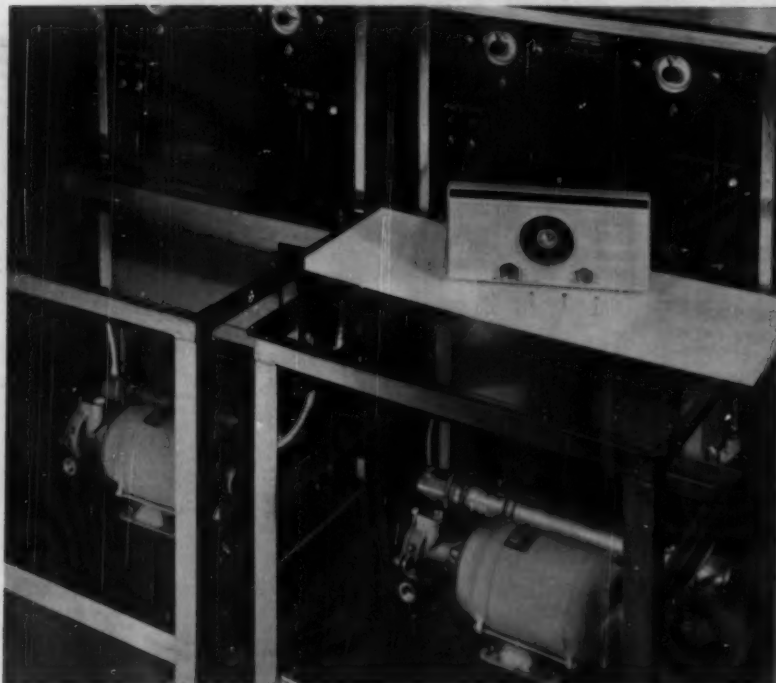
"These Eco Pumps have proven very satisfactory," says Dr. Worne of Pharmaceutical Industries. "They provide beautiful suction lift where required, offer no contamination problem either from air ingress into the system or from materials of construction, and supply continuous, linear flows most suitable to our needs."

"We now have standardized on Eco Pumps—following an early unfortunate experience with centrifugals of another make."



Close-up of one of the Eco ALL-CHEM 1750 rpm direct motor driven units at Pharmaceutical Industries, Inc.

## "BEST PUMPS IN THE PLANT", Say Sylvania Maintenance Men



New Sylvania Production Units for processing Radio Transistors, being equipped with Eco CENTRI-CHEM Pumps

This is a story of pump economics. Sylvania Electric Company, Division of International Telephone and Telegraph Company, were using an inexpensive make of pumps in recirculating systems containing dilute hydrogen peroxide in warm water. However, low first cost was soon offset by extensive maintenance and expensive loss in production time.

### Studied Advantages

Sylvania and Eco engineers discussed in detail the advantages of high nickel alloys and Teflon-ceramic mechanical seals, as used in the Eco CENTRI-CHEM centrifugal before trying out the first Eco pump.

### Results Pay Off

The savings were apparent from the beginning as there have been no pump break-

downs or replacement parts required, no interruptions of production—although these pumps operate twenty-four hours a day, six days a week, and some of them have now been in service for more than 2 years.

Successful pump installations don't just happen. They are planned. This typical Eco success story highlights two important advantages of doing business with Eco—good products and close cooperation between Eco and customer engineers to insure sound application economics.

### Standardize on Eco

Sylvania now standardizes on Eco CENTRI-CHEM Pumps for all similar pump requirements in their multi-plant complex and Sylvania maintenance men refer to them as, "The best pumps in the plant."

### ECO Products for Handling Corrosive and Hazardous Processing Fluids

**ALL-CHEM® Rotary Pumps**  
**MINILAB® Rotary Pumps**  
**GEARCHEM® Gear Pumps**  
**CENTRI-CHEM® Centrifugal Pumps**

**PUMPMOBILE® Portable Pumping Units**  
**GEAR-VAC® Valves**  
**CHEMICAL DISPENSING VALVES**  
**Factory Mutual Approved**

Ask for literature on any or all of these ECO Products

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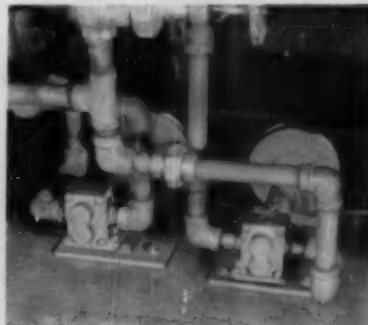
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## Circulating Caustic and Nitric Acid Baths in Wire Finishing



Side by side, these two identical GEARCHEM Pumps, sharing the same motor, pump media at opposite ends of the pH scale, simultaneously. They are 316 stainless steel, equipped with Hastelloy®C gears for corrosion resistance in both acid and caustic environments, and also to withstand the abrasion of fragments of metal remaining from the wire drawing operations, which accumulate in the baths.

\*T.M. Union Carbide Corp.

# VAREC

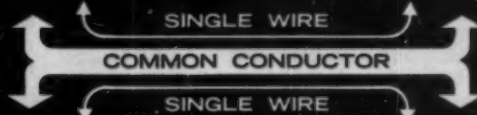
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Series 882 control unit for pump motors provides two-status control, such as "off" and "on."



Series 886 field unit for pump motor control.



Series 883 control unit for valve operators provides for three-position control—"open," "close," and "stop."



Series 887 field unit for valve operator control.



The Varelectric 880 Series provides direct, instantaneous control of pump motors, valve operators and similar electrically-operated equipment, while continuously supervising and indicating the status of the controlled devices. Using only one wire between each field and control unit, *plus a common conductor for many units*, a Varelectric system can cut field wiring costs to as little as 25% to 15% of that of conventional systems—which often require from seven to nine wires between individual units.

### VARELECTRIC offers these advantages:

- **ECONOMY:** Saves from 75% to 85% of field wiring costs...uses two wires instead of many.
- **RELIABILITY:** Uses continuous, well-filtered, direct current...no AC or DC pulsating current used.
- **PRECISION:** Uses the bridge circuit concept...inherently detects trouble.
- **FLEXIBILITY:** Modular construction provides for flexibility of application...dustproof case attaches to operator's control panel.
- **BROAD APPLICATION:** Varelectric systems can control any electrically-operated equipment up to three statuses.

For applications in the petroleum and chemical industries, or wherever control is vital, Varelectric furnishes the most modern, economical solution to control problems. For full details, send for Bulletin CP-3708. Write Dept. CEP-1141-1.



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## Washington – Big program features chem engineering in Government

**Giant 35-session technical program to highlight Army Chemical Corps activities—plus outstanding symposia in almost every area of the chemical engineering profession.**

"CHEMICAL ENGINEERING in Government Programs" is the leading theme of the 35-session Annual Meeting of A.I.Ch.E. coming up in Washington, D.C., December 5 to 7. In fact, twenty-two of the sessions will be clearly associated with Government programs.

The extensive chemical engineering knowledge which the Army Chemical Corps has developed on aerosol generation techniques will be brought out during a comprehensive symposium scheduled for Tuesday morning and afternoon. Also contributed by the Chemical Corps will be a two-session symposium (Wednesday morning and

afternoon) on *Toxic Plant Construction* which will detail the extreme design and operating precautions needed in the manufacture of supertoxic materials such as nerve gases or biological warfare agents.

Two symposia of outstanding timeliness—*Saline Water Conversion* and *Automobile Exhaust Afterburners*—will be among the sessions starting on Monday afternoon, following the Institute's annual business meeting on Monday morning. Monday evening feature will be an unrehearsed informal round-table discussion on *Air Pollution Problems*.

The so-called "classical" areas of

chemical engineering will not be neglected in the Washington technical program. Symposia are scheduled on *The Unsteady State as an Analysis Tool in Chemical Engineering* (3 sessions), *Heat Transfer, Phase Transitions, Fluid Dynamics*.

Featured also at Washington will be the "11 o'clock lecture." On Tuesday at this time, the speaker will be S. F. Singer, University of Maryland astro-physicist: his subject—*Scientific Exploration of Space*. Speaker on Wednesday morning, also at 11 o'clock, will be Wallace R. Brode, recently Science Advisor to the Secretary of State, who will speak on *Scientific and Engineering Planning*. No technical papers sessions will be held during these special feature lectures.

Full program for the Washington meeting is given below, details of special events and extra-curricula activities will follow in CEP in November.

#

*A personal impression of the trials and tribulations of the program committee in whipping the technical program into shape will be found in the Letters column of this issue of CEP, page 27.*

## Three-Day Schedule of Technical Sessions

### MONDAY, DECEMBER 5

2:00-5:00 P.M.

#### TECHNICAL SESSION NO. 1—PROPELLANT PROCESSING—PART 1

Chairman: W. E. Sheehan, Dept. of Defense. Manufacture of nitrocellulose base propellants. A. M. Ball, Hercules Powder. Solvent extrusion, solvent emulsion, rolled sheet, solventless extrusion, cast double base, slurry casting processes.

Liquid polysulfide polymer manufacture, E. R. Bertossi & W. D. Helmer, Thiokol Chemical. Manufacture of sodium polysulfide and dichloroethyl formal.

Chemical engineering in solid propellant processing, H. O. Holley, Thiokol Chemical. Process for manufacturing cast, composite solid propellant.

Continuous processing of Arcite solid propellants, R. N. Saleeby, Jr., Atlantic Research. Novel extrusion techniques for grain production.

The radioisotope method for determining weight per cent of an ingredient during solid propellant mixing, R. A. Peterson, Aerojet-General. Tracer technique for rapid weight determination. "Minuteman—Missile and Mission,"—Air Force motion picture film.

#### TECHNICAL SESSION NO. 2—SALINE WATER CONVERSION—PART 1

Chairman: J. J. Strobel. Vice-chairman: R. H. Jebeles, Dept. of Interior. Status of saline water conversion, J. J. Strobel. Scope of scientific and technical activity from basic research to commercial plants. Scale formation in sea water evaporators.

F. C. Standiford & J. R. Sinek, W. L. Badger Assoc. Theoretical aspects, actual and proposed methods.

Multiple effect rotating evaporator—design considerations, preliminary tests, and predictions of performance of a 28 effect unit, R. L. Clark & L. A. Bromley, Univ. of Calif. Performance prediction under various operating conditions.

Evaluation of electrodialysis membranes and equipment, H. J. Cohan, Dept. of Interior. Commercially available electrodialysis equipment and membranes.

Energy balance in solar distillers, J. A. Eibling, Battelle Inst. & G.O.G. Lof, Denver. Solar distiller productivity and efficiency over range of typical operating conditions.

Saline water conversion by freezing with hydrocarbons, G. Karnofsky, Blaw-Knox. Refrigeration cycle with direct contact between butane and water in both freezing and melting steps.

#### TECHNICAL SESSION NO. 3—AUTOMOBILE EXHAUST AFTERBURNERS

Chairman: W. L. Faith, Air Pollution Found. Co-chairman: A. J. Teller, Colonial Iron Works.

The design and performance of a best-straping direct-flame afterburner, S. L. Ridgway, Thompson-Ramo-Wooldridge. Heat of burnt exhaust gas utilized to preheat incoming mixture.

Catalytic conversion of automobile exhaust gases by Purzuaat, C. F. Gerald & V. Haensel, UOP. Development of catalyst and converter resulting in the Purzuaat device.

The use of structural ceramics to satisfy requirements of catalytic exhaust converters—Part 1. D. L. O'Brien & L. L. Johnson, Min-

nesota Mining and Manufacturing. Advantages include short heat-up time, no attrition losses, low pressure drop.

The use of structural ceramics to satisfy requirements of noncatalytic automobile exhaust converters—Part 2. W. C. Johnson & L. L. Johnson, Minnesota Mining and Manufacturing. A practical means of obtaining a satisfactory maximum temperature.

Laboratory evaluation of a catalytic muffler, W. B. Innes, American Cyanamid. Performance requirements, test methods, catalyst development and screening techniques.

#### TECHNICAL SESSION NO. 4—INFORMATION AND COMMUNICATION

Chairman: R. E. O'Dette, National Science Found.

A National program for better information service, B. W. Adkinson & R. E. O'Dette, National Science Found. Specific roads towards improvement.

Information, please, W. T. Knox, Esso Res. & Eng. Use of published technical information in research, development, engineering, A.I.Ch.E. standards to aid information retrieval, R. D. Morse, Du Pont. Use of concept-coordination index systems by publisher. Inside information, R. L. Taylor & L. E. Rasmussen, Du Pont. Mechanized retrieval of technical information within a central engineering department.

Information retrieval made difficult, D. R. Swanson, Thompson-Ramo-Wooldridge. Machine search of text: an approach to the identification of fundamental problems.

#### TECHNICAL SESSION NO. 5—ECONOMIC EVALUATION OF NEW PROCESSES

Chairman: J. H. Hirsch, Gulf Res. & Devel.



**Estimating plant investment costs.** J. H. Hirsch & E. M. Glasier, Gulf Res. & Devel. An improved procedure for calculating total plant investment from size and cost of basic equipment.

**Estimating offsite investment and working capital.** S. P. Dickens & F. R. Douglas, Texaco. A general summary.

**Techniques for evaluating petroleum processes.** F. T. Barr, Esso Res. & Eng. Operating cost estimating, the economic evaluation step, short cuts for rough evaluation and projection-type economics.

**Venture analysis—a method of long range planning.** S. L. Andersen, Du Pont. The use of computer simulation.

#### TECHNICAL SESSION NO. 6—PHASE TRANSITIONS—PART 1

Chairman: S. G. Bankoff, Northwestern Univ. Co-chairman: M. Markels, Jr., Atlantic Research.

**Nucleation and condensation.** P. R. Basford, Ford Motor. Proposed more general theory of nucleation and condensation in a rocket exhaust.

**Film boiling on hydrodynamic bodies.** W. B. Bradfield, R. O. Barkdoll, & J. T. Byrne, Convair. Effects of subcooling, surface condition, geometry, and chemical reaction on hydrodynamics of force and forced convection quenching.

**An equation of state for the liquid and vapor states of nitrogen.** B. F. Bukacek & R. E. Peck, III, Inst. of Tech. An equation of state accurate up to three times the critical temperature density.

**Diffusion and equilibrium studies for the system acrylonitrile-styrene-polyethylene.** H. W. Chandler, Radiation Applications, & E. J. Henley, Stevens Inst. of Tech. Solubilities and diffusivities measured at 27°C using radiation-induced polymerization technique.

**Vapor-liquid equilibrium constants: their prediction for binary systems up to the critical point.** V. S. Mehra & G. Thodos, Northwestern Univ. Correlations developed for the binary systems: ethane-n-heptane, ethane-n-butane, and n-butane-n-heptane. Correlations tested on several other systems.

#### TECHNICAL SESSION NO. 7—FEEDING, CLOTHING AND PROTECTING THE COMBAT SOLDIER

Chairman: L. A. Spano. Vice-chairman: D. L. Fiske, QM R&E Command.

**Transient-state temperature distribution in the human.** E. H. Wisler, Univ. of Texas. Development of a mathematical model.

**Absorption of thermal radiation and heat flow through protective systems.** J. Davies &

E. S. Cotton, QM R&E Command. Optical and thermal properties of protective shield and spacings away from skin are important factors.

**Freeze drying of foods for the armed services.** J. M. Tuomy, QM Food and Container Inst. Economics of freeze drying depend on rate of heat transfer to subliming surface.

**The effect of thermal radiation on textile materials.** A. J. McQuade & E. T. Waldron, QM R&E Command. Methods used to simulate thermal effects, to equate materials to common basis, and to measure effectiveness.

**Structure and properties of non-flammable nitroso rubber.** QM R&E Command. A new experimental rubber having a heteroatomic structure as the repeating unit in the molecular chain.

**Rapid thermal degradation of polymers.** QM R&E Command. Certain fluoropolymers found to have good heat dissipating properties.

#### TECHNICAL SESSION NO. 8—CHEMICAL ENGINEERING IN THE MINERAL INDUSTRIES

Chairman: H. Ferry. Vice-chairman: R. M. Jameson, Bureau of Mines.

**The effects of ultrasonics on the electrodeposition of metals from aqueous solutions.** D. Schlain & C. B. Kenahan, Bureau of Mines. Effects of high-frequency sound on electrodeposition of copper, zinc, manganese, manganese dioxide.

**Vapor pressure and activity coefficient determinations for zinc in zinc-aluminum alloys by a gas-transport method.** J. D. Donhee, Bureau of Mines. Principles of the method, test equipment and procedures.

**Recovery of zinc from galvanizers' dross and zinc-base-die-cast scraps by filtration.** J. A. Ruppert, Bureau of Mines. Dross and die-cast melted together to form solid iron-aluminum compounds in molten zinc.

**Radiant drying of coal filter cake.** E. R. Palowitch, Bureau of Mines. An attempt to increase water removal capacity of vacuum filtration.

**Hydrogen from coal via a fluidized steam-iron process.** J. H. Field, A. J. Forney & S. J. Gaciur, Bureau of Mines. The steam-iron reaction for producing hydrogen using fluidized bed of iron oxide in reduction and oxidation steps.

**Round Table Discussion—Air Pollution Problems—Interrelationship of Factors.** Moderator: W. L. Falth, Air Pollution Found. Participants: A. Arch, Air Pollution Control Assoc., Pittsburgh; C. A. Bishop, United Steel; D. Sweeney, Socony Mobil Oil; W. R. Taylor, Diamond Alkali.

Unrehearsed, informal discussion of non-chemical engineering factors involved in air pollution control.

## TUESDAY, DECEMBER 6

9:00-11:00 A.M.

#### TECHNICAL SESSION NO. 9—PROPELLANT PROCESSING

Chairman: W. E. Sheehan, Dept. of Defense. The Manufacture of perchlorates, T. W. Clapper & J. E. Reynolds, American Potash & Chemical. Particular reference to ammonium, potassium and lithium perchlorates. A process for the large scale production of diborane, R. A. Brown, Callery Chemical. Details of a continuous large-scale production process.

**Fluorine containing liquid propellants.** J. F. Gell, Pennsalt Chemicals.

**The manufacture of unsymmetrical dimethyl hydrazine.** L. H. Diamond, Food Machinery & Chemical. Chemical engineering aspects of the two most important methods.

**High strength hydrogen peroxide—large scale manufacture, storage, handling and safety.** S. S. Nalstai & J. B. Ryan, Food Machinery & Chemical. Distillation and fractional crystallization techniques to raise concentration to 90-100% by weight.

**TECHNICAL SESSION NO. 10—SALINE WATER CONVERSION—PART 2**

Chairman: J. J. Strobel.

Vice-chairman: L. J. Winchester, Dept. of Interior.

**Vapor reheat flash evaporation—saline water conversion without metallic condensing surface.** D. F. Othmer, R. F. Benenati, & G. C. Coulandris, Polytechnic Inst. of Brooklyn. Detailed process description.

**Heat transfer in a spray column.** T. Woodward, Food Machinery & Chemical. Experimental spray columns operated as heat exchangers.

**Use of aluminum for sea water distillation equipment.** R. J. Galsney, Eng. R&D Labs. Corrosion difficulties avoided by eliminating all copper alloys from system.

**The hydrate process—engineering aspects.** W. G. Knox, M. Hess, G. E. Jones, Jr., & H. B. Smith, Jr., Koppers. Process described, compared with other conversion methods.

**TECHNICAL SESSION NO. 11—EVALUATION OF EQUIPMENT USED FOR AIR POLLUTION CONTROL**

Chairman: A. J. Teller, Colonial Iron Works. Co-chairman: C. Keleti, American Cyanamid.

continued on page 116

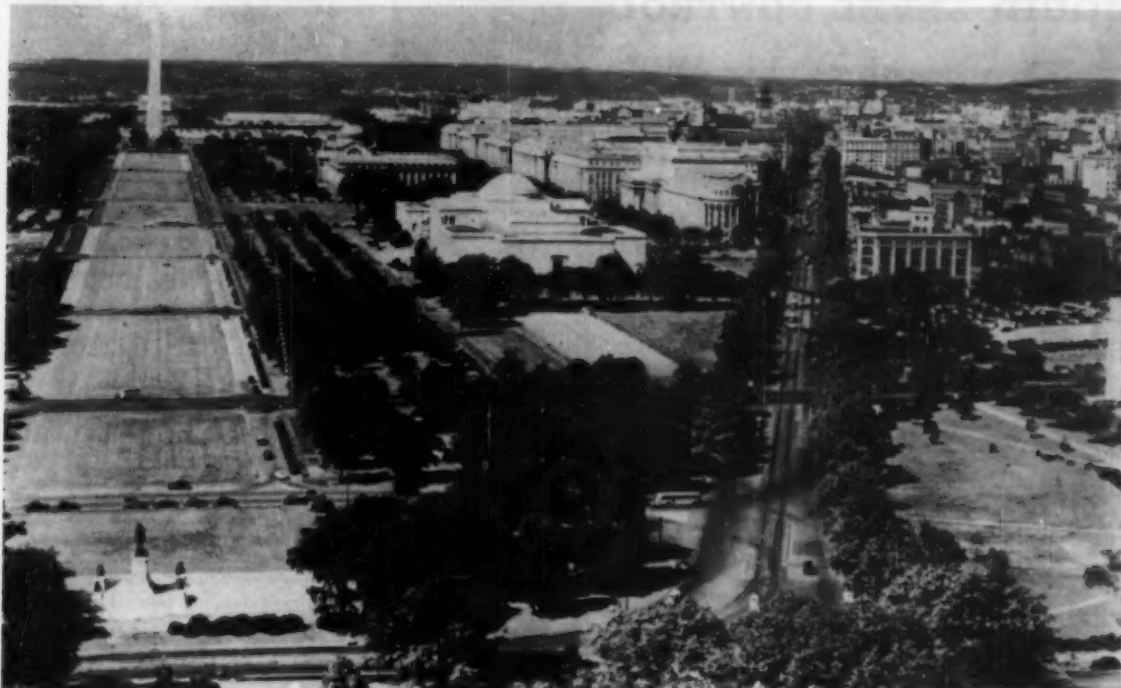


Photo courtesy of Washington Convention and Visitors Bureau.

## Technical sessions

from page 115

**Development of floating bed scrubbers.** A. W. Kielback, Aluminum Co. of Canada. Solution of tar fouling problem by low density spheres as packings in floating-bed scrubbers. Collection of small particles in baffled conduits. R. Hodous & S. Calvert, Case Inst. of Tech. Use of rectangular ducts with series of transverse baffles on one wall. Role of electrostatic precipitators in air pollution abatement. A. B. Walker & E. J. Malarkey, Research-Cottrell. Use in removing particulate matter from industrial waste gases. Practical approach to air pollution control through portable pilot and analytical equipment. E. M. Igenfrits & G. A. Baker, Dow Chemical. Uses of a lightweight, fiberglass-reinforced, one-foot diameter scrubber tower. Costs of wet scrubbing gases. N. Gilbert, Univ. of Cincinnati. Operating costs compared for 14 different classes of collectors.

### TECHNICAL SESSION NO. 13—DISPERSAL OF MATERIAL IN THE AEROSOL FORM—PART 1

Chairman: L. E. Garono.  
Co-chairman: R. D. Kracke, Chem. Res. & Devel. Labs.  
Methods of disseminating chemical agents. D. M. Lipnick, Chem. Corps Eng. Command. Principles and designs of items used by U.S. Army Chemical Corps.  
Recent dispersion equipment developments. R. L. Brown, Jr., Chem. Corps Eng. Command. Latest developments employ pulse jet and gas turbine principles.  
Free fall breakup of a liquid mass. A. R. Palmer, J. D. Wilcox, & J. V. Pistrutto, Chem. Res. & Devel. Labs. Photographs, time, distance, velocity of fall.  
A study of the factors influencing the flashing of liquid aerosols. J. V. Pistrutto & J. D. Wilcox, Chem. Res. & Devel. Labs. Test results on n-dodecane, cis-decalin, and ethylene glycol at elevated temperatures.  
Some technical problems in the generation of aerosols for inhalation studies. C. L. Punte

& E. J. Owens, Chem. Res. & Devel. Labs. Techniques for preparing atmospheres containing aerosols for laboratory inhalation studies.

### TECHNICAL SESSION NO. 13—HEAT TRANSFER

Chairman: M. Altman, G.E.  
Vice-chairman: L. Bernath, Du Pont.  
Variable mesh size in iteration methods of solving partial differential equations and application to heat transfer. G. F. Round, R. Newton, & P. J. Redberger, Res. Council of Alberta. Four types of variable mesh systems. The conduction of heat from a flat metal surface to a moving bed of glass beads. N. K. Harakas & K. O. Beatty, Jr., North Carolina State. Theoretical and experimental data.  
Heat transfer from acoustically resonating gas flames in a cylindrical burner. W. M. Zartman, Humble Oil & Refining, & S. W. Churchill, Univ. of Mich. Determination of local heat transfer coefficients.  
Direct correspondence of mass, heat and momentum transfer in the flow of gases past single spheres. Yin-Chao Yen, Army Corps of Eng., & G. Thodos, Northwestern Univ. Experimental determinations for turbulent flow.

### TECHNICAL SESSION NO. 14—PHASE TRANSITIONS—PART 2

Chairman: S. G. Bankoff, Northwestern Univ.  
Co-chairman: M. Markels, Jr., Atlantic Research.  
Effects of bubbling and stirring on mass transfer coefficients in liquids. J. D. Polejes & O. A. Hougen, Univ. of Wis. Revised correlation of mass-transfer data.  
Multimolecular adsorption equation. R. R. Rousley, Mead Corp. Equation derived for the range where capillary adsorption is insignificant.  
High pressure vapor-liquid equilibria by gas-liquid partition chromatography. F. H. Stalcup & R. Kobayashi, Rice Univ. Determination of K-values of methane and n-butane in n-decane at temperatures from 160 to 40°F for pressures up to 1,300 lb./sq. in.  
Isothermal growth of hydrogen bubbles during electrolysis. D. E. Westerheide & J. W. Westwater, Univ. of Ill. Growth of hydrogen bubbles under mass-diffusion control studied

at a platinum cathode in water.

### TECHNICAL SESSION NO. 15—GOVERNMENT PROGRAMS AND CHEMICAL ENGINEERING EDUCATION

Chairman: W. K. Davis, Bechtel.  
Government programs aiding higher education. R. G. Folsom, Rensselaer Polytech. A review of grants-in-aid, types of contracts, agencies involved.  
Importance of sponsored research in strengthening chemical engineering graduate programs. C. E. Grove, Jr., Syracuse Univ. Review of programs at Syracuse Univ.  
The AEC educational assistance program in reactor technology. J. P. Kaufmann & G. V. Packer, AEC. Review of program initiated in 1956.  
Government's new patent philosophy. D. B. Keyes, NAM. The trend in patent ownership.

### TECHNICAL SESSION NO. 16—SELECTED PAPERS

Chairman: E. J. Gruen, Atlantic Research.  
A radiotracer determination of entrainment in a bubble-cap column. V. Dorweiler & G. Burnett, Iowa State Univ. Development of a new technique.  
Explosion and detonation studies of gas mixtures encountered in electrolytic chlorine production. W. C. Eichelberger, B. B. Smura, & W. R. Berggren, Allied Chemical, Solvay Div. Determination of lower detonable limit of industrial electrolytic chlorine gas.  
Sulfuric acid—optimized conditions in contact manufacture. A. C. Homme & D. F. Othmer, Brooklyn Polytech. Utilization of a digital computer.  
Characterization of Kuwait diesel fuel by the hydrodesulfurization of dibenzothiophene. R. A. Mahugh & L. Bert, Montana State College. Kinetic data on reaction between hydrogen and benzoethiophene. Effect of various diluents on reaction rate constant.

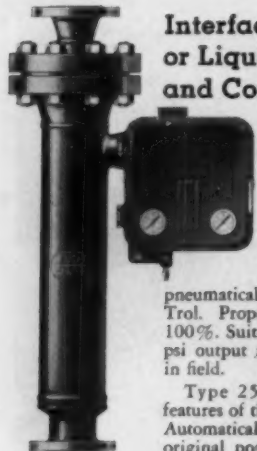
2:00-5:00 P.M.

### TECHNICAL SESSION NO. 17—THE UNSTEADY STATE AS AN ANALYSIS TOOL IN CHEMICAL ENGINEERING—PART 1

Chairman: T. J. Williams, Monsanto.  
Vice-chairman: O. L. Updike, Univ. of Virginia.  
Limitations of correlation techniques in determining process frequency response. P. W. Gallier, T. H. Puckett, & C. M. Cilepcevich.

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Univ. of Okla. Studies on a continuous stirred-tank reactor.

**Pulse testing—its advantages and limitations.** J. O. Hogen & R. A. Walsh, Monsanto. A method for obtaining process dynamics.

**The moments method of analysis and its application to mixing dynamics.** R. E. Otto & L. E. Stout, Monsanto. Application to the dynamic description of an agitated vessel.

**Transient versus frequency response in analyzing chemical process control problems.** N. H. Csanika, Univ. of Minn. A number of methods compared.

**Latest techniques in the analysis of kinetic systems.** L. Lapidus, Princeton Univ. Emphasizing the mathematical concepts and use of computers.

#### TECHNICAL SESSION NO. 18—SOLVING POLLUTION CONTROL PROBLEMS

Chairman: A. J. Teller, Colonial Iron Works. Co-chairman: W. A. Burns, American Oil.

**Air pollution activities associated with alkaline pulping.** E. R. Hendrickson, Univ. of Florida. Evaluation of newer methods.

**The control of solvent emissions from surface coating operations.** C. V. Kanter, Los Angeles Air Pollution Control Dist. An evaluation of approaches.

**Sewage plant treatment exhaust.** R. R. Calacelo, Automotive Rubber. Performance of a cyclonic jet scrubber.

**Sulfuric acid mist control.** R. V. Wallace, Stauffer. Methods for reduction of SO<sub>2</sub> and SO<sub>3</sub> emission.

**Catalytic removal of nitrogen oxides and hydrocarbons from exhaust streams.** F. R. Taylor, Franklin Inst. Use of chromite catalysts.

**Control of air-borne emissions from alkaline pulping.** M. J. Lardieri, National Council for Stream Improvement. Description and evaluation of control methods.

#### TECHNICAL SESSION NO. 19—CHEMICAL ENGINEERING IN BROADENING THE USE OF AGRICULTURAL CROPS

Chairman: J. E. Simpson, Dept. of Agriculture. Vice-chairman: D. L. Miller, Dept. of Agriculture.

**Introduction—What is utilization research in the U.S. Department of Agriculture?** J. E. Simpson, Dept. of Agriculture. Broad orientation in the objectives and program.

**Bridging utilization engineering development to industrial usage.** D. L. Miller, E. L. Griffin, Dept. of Agriculture. How USDA utilization engineering research works with industry.

**Chemical engineering in fermentative processing.** V. E. Bohns, Dept. of Agriculture. Chemical engineering aspects of USDA research and development.

**Engineering research in food processing.** W. D. Ramage, Dept. of Agriculture. Process development at USDA Western Utilization Research and Development Div.

**Applications of chemical engineering to food process development.** R. K. Bakewell & N. C. Accio, Dept. of Agriculture. Application of chemical engineering principles.

**Role of chemical engineering in cotton processing.** E. L. Patton, H. L. Vix, Dept. of Agriculture. Processes for new chemically-modified cotton products.

#### TECHNICAL SESSION NO. 20—DISPERSAL OF MATERIAL IN THE AEROSOL FORM—PART 2

Chairman: L. E. Garono, U.S. Army Chem. Corps Res. Command.

Co-chairman: R. D. Kracke, U.S. Army Chem. Res. & Devel. Labs.

**Immersion sampling of spray droplets.** R. W. Tate, Delavan Mfg. The mechanics of the immersion technique.

**Chemiluminescent sampler.** R. L. Wilburn, J. H. Frank, & G. W. Wooten, U.S. Army Chem. Corps. Samples, analyses, and records concentrations of various oxidants in air or liquids.

**The aerosol and spray fall-out meter.** R. D. Kracke & A. Pfeiffer, U.S. Army Chem. Res. & Devel. Labs. Description and operation.

**The measurement of the properties and parameters of small particle aerosols in cloud chambers.** E. W. Larson, U.S. Army Chem. Corps Biol. Labs. Facilities, equipment, operational methods, techniques.

**Some considerations in wind tunnel studies of aerosols.** E. J. Owens & C. L. Punte, U.S. Army Chem. Res. & Devel. Labs. Study of physical characteristics of aerosol clouds.

**A preliminary theoretical study of the cloud travel of coarse aerosol particles.** D. O. Eigner, D. Campbell, R. L. Campbell, & J. S. Tyler, Jr., U.S. Army Chem. Res. & Devel. Labs. Proposed technique for modifying Sutton's diffusion equations.

continued on page 118

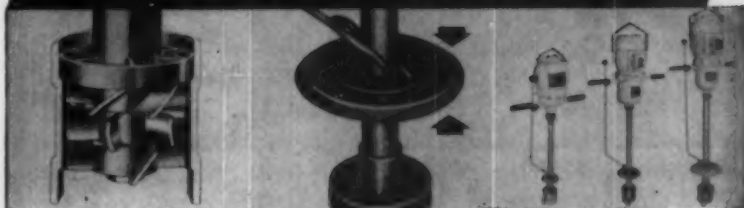
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## Technical sessions

from page 117

### TECHNICAL SESSION NO. 21—HEAT TRANSFER—PART 2

Chairman: O. E. Dwyer, BNL.  
Vice-chairman: R. A. Tibball, Griscorn-Russell.  
Heat transfer to hydrogen and helium with wall to fluid temperature ratios to 11,001. H. Wolfe & J. R. McCarthy, Rocketdyne. Experiments on gases flowing turbulently without acoustic resonance in smooth, round, electrically heated tubes.  
Heat transfer to a flame deflector, B. L. McFarland, Aerojet-General. Heat transfer conditions on a flat plate normal to the axis of a high velocity jet.  
Partial pressure and temperature gradients from solid catalyst particles in fixed beds to ambient fluid streams, F. Yoshida, D. Ramaswami, & G. A. Hogen, Univ. of Wis. Methods of predicting partial pressure and temperature gradients.

Heat transfer in a chemically reacting system ( $N_2O_4$ ), J. P. Irving & J. M. Smith, Jet Propulsion Lab. Equations for effective properties derived from heat transfer considerations.

Thermal conductivity of heterogeneous materials, R. L. Goring & S. W. Churchill, Univ. of Mich. Methods of predicting steady state thermal conductivity of many two-phase materials of commercial interest.

The effect of acoustic vibration on forced convective heat transfer, R. Lemlich & Chung-Kong Hwu, Univ. of Cincinnati. Qualitative dual mechanism proposed.

Theoretical calculation of turbulent mass and heat transfer coefficients in a packed bed, K. F. Gordon, Univ. of Mich. Equation derived for the  $J$ -factor in packed beds.

### TECHNICAL SESSION NO. 22—SALES OVERSEAS

Chairman: J. T. Costigan, Sharples.  
Vice-chairman: N. H. Parker, Tower Iron Works.  
Overseas financing, D. Polderman, Whiting Corp.  
Overseas manufacturing, J. J. Serrell, Sharples.

Overseas agents vs. foreign licensing, R. G. Biesel, General American Transportation. Expanding overseas trade, C. Norberg, Atorney at Law. Round-table discussion, I. Hutchinson, Dow Corning (other participants to be announced).

### TECHNICAL SESSION NO. 23—FUEL CELLS AS POWER SOURCES

Chairman: P. S. Greer, Ordnance Res., U.S. Army.  
Vice-chairman: S. J. Magram, Army Res. Office.

Fuel cells: current status, types and state of achievement, S. J. Magram. A review of many types.

Fuels for fuel cells, G. E. Evans, Union Carbide. Brief examination of organic and inorganic fuels.

The oxygen electrode in aqueous fuel cells, E. Yeager, Western Reserve Univ. Factors which control performance characteristics.

Performance of fractional watt ion exchange membrane fuel cells, E. J. Cairns & L. W. Nienisch, G. E. Effect of design and operational variables on performance.

Fuel cells based on nuclear reactors, T. A. Chiarliello & R. C. Werner, MSA Research. Ionic hydride fuel cell shows promise of being thermally regenerative directly or indirectly by a nuclear heat source.

### TECHNICAL SESSION NO. 24—NUCLEAR PLANT SAFETY

Chairman: C. E. Dryden, Ohio State Univ. Co-chairman: C. D. Luke, AEC.

Nuclear chemical plant design—criticality considerations, N. Ketsch, Atomica International. Establishment of proper safety criteria.

Radiation protection factors in nuclear chemical plant safety, A. R. Keene, Hanford Labs (G.E.). Bases of an effective radiation safety protection program.

Nuclear chemical plant design—shielding, E. P. Blizard, ORNL. New shielding design concepts.

Safety considerations in aqueous reprocessing plant operations, W. G. Morrison, Phillips Petroleum. Procedures for control and confinement of flammable and radioactive materials.

Radiochemical processing—off-site transportation and ultimate storage problems, J. O. Blomke & L. B. Shappert, ORNL. Consideration of safe and economic methods of handling radioactive materials.

Case histories of accidents in nuclear chemical plants, D. S. Hayes, AEC. Lessons learned and corrective action taken.

WEDNESDAY, DECEMBER 7

9:00-11:00 A.M.

### TECHNICAL SESSION NO. 25—CHEMICAL ENGINEERS IN RESEARCH AND ENGINEERING IN THE AIR FORCE—PART 1

Chairman: J. V. Hearn, U.S. Air Force.  
Vice-chairman: P. L. Hill, Air Material Command.

Air Force futures in chemistry, A. G. Horney, A.P. Office of Scientific Research. Role of the chemical industry in basic research.

USA, production of hydrazine by nuclear reaction, M. R. Gustavson, J. H. Cusack, & R. I. Miller, Aerojet-General Nucleonics. Feasibility of the direct, in-reactor production of hydrazine from liquid ammonia.

Ion propulsion working fluid requirements for USAF, J. H. L. Lawlor, Wright Air Dev. Div. Probable requirements for ion engine working fluids, systems for producing power, handling needs.

### TECHNICAL SESSION NO. 26—THE UNSTEADY STATE AS AN ANALYSIS TOOL IN CHEMICAL ENGINEERING—PART 2

Chairman: T. J. Williams, Monsanto.  
Vice-chairman: W. F. Stevens, Control Data Corp.

Dynamic heat removal from a jacketed agitated vessel, W. S. Stewart, T. H. Puckett, & C. M. Silepovich, Univ. of Okla. Comparison of results from different response techniques. The mobile data logger—requirements for its design and use, D. E. Johnson & F. E. A. Cowley, Shell Development. Evolution from a two-channel analog to a twenty-channel analog and digital facility.

Magnetic tape recording and digital computer analysis with mobile data loggers, J. F. Draffen, J. B. Jansen, & M. C. Bird, Monsanto. Advantages and limitations of magnetic tape recording equipment.

Status of chemical analysis instrumentation for following the transient response of chemical reaction processes, M. D. Weiss, Union Carbide. Comprehensive list of chemical analysis instrumentation available commercially.

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#### TECHNICAL SESSION NO. 27—TOXIC PLANT CONSTRUCTION—PART 1

Chairman: L. E. Garono, U.S. Army Chem. Corps Eng. Command.  
Vice-chairman: M. G. Fingers, U.S. Army Chem. Res. & Devel. Labs.

**The PDW story—chemicals for defense.** S. Tonetti, U.S. Army Chem. Corps Material Command. Operation of a facility in support of the nerve gas program.

**Toxic pre-pilot plant processing.** S. R. Eckhaus, U.S. Army Chem. Res. & Devel. Labs. Details of the Chemical Corps' facility.

**Design of pilot plants for toxic chemicals.** A. B. Rhodes & J. C. Richards, U.S. Army Chem. Res. & Devel. Labs. Isolation of toxic operations, remote control operability, equipment accessibility.

**Heating and ventilating for toxic chemical plants.** E. T. Rock, U.S. Army Chem. Corps Eng. Command. Heating, ventilating, decontamination procedures.

#### TECHNICAL SESSION NO. 28—THE ROLE OF THE CHEMICAL ENGINEER IN ENVIRONMENTAL HEALTH ENGINEERING—PART 1

Chairman: W. L. Faith, Air Pollution Found. Introduction, W. L. Faith, Role of the chemical engineer in the total field.  
**Government problems in environmental health.** L. E. Burney, Surgeon General, U.S. Public Health Service. New modes of cooperation among governmental agencies and other segments of the economy.

**Industrial problems in environmental health.** J. E. Hull, MCA. Effect of current legislation and technological advances on the chemical industry.

**Educational problems in environmental health.** J. E. McKee, Calif. Inst. of Tech. Requirements in undergraduate and graduate engineering courses.

#### TECHNICAL SESSION NO. 29—NUCLEAR REACTORS—OPERATING EXPERIENCE

Chairman: R. L. Cummings, Atomics International.

**Experimental boiling water reactor—operation and maintenance.** E. A. Wimbune, ANL. An account of three years of operation.

**Operation of the Shippingport Atomic Power Station.** F. C. Duvall, Shippingport. Integration of the Shippingport facility into an existing utility system.

**Operation experience with the sodium reactor experiment.** R. E. Durand, Atomics International. Review of information gained during operation.

**Organic moderated reactor experiment—equipment, operation and maintenance.** N. J. Swanson, Atomics International. Three years of operation of the organic moderated reactor experiment.

2:00-3:00 P.M.

#### TECHNICAL SESSION NO. 30—CHEMICAL ENGINEERS IN RESEARCH AND ENGINEERING IN THE AIR FORCE—PART 2

Chairman: J. V. Hearn, U.S. Air Force.  
Vice-chairman: P. L. Hill, Air Material Command.

**The chemical engineer in Air Force materials research.** L. F. Salzburs, Wright Air Devel. Div. Role of the chemical engineer in research and development.

**A relaxation time technique for the measurement of thermal diffusivity.** G. Sonnenschein & R. A. Winn, Wright Air Devel. Div. Newly-developed method for measuring thermal diffusivity of solids.

**Wright Air Development Division structural materials applied research for manned reentry vehicles.** D. H. Cartolano, A. Olevetch, & J. R. Myers, Wright Air Devel. Div. Analysis of materials problems and requirements posed by the thermal environment in reentry phase of a manned vehicle.

**Purification and purification of very high purity materials.** A. F. Armstrong & B. Rubin, Air Force Cambridge Research Center. Purification techniques in preparation of solid-state semi-conductor materials.  
**Ultra high pressure research.** W. G. Field, Air Force Cambridge Research Center. Development of several types of ultra-high pressure equipment.

#### TECHNICAL SESSION NO. 31—THE UNSTEADY STATE AS AN ANALYSIS TOOL IN CHEMICAL ENGINEERING—PART 3

Chairman: T. J. Williams, Monsanto.

Vice-chairman: W. H. Abraham, Du Pont.  
**Some special purpose computers and their use in data gathering and analysis.** J. F. Pink, Compudyne Corp. Applications to process control.

**Status of physical property measurement instrumentation in fast response applications.** V. A. Lauher & T. J. Williams, Monsanto. A

continued on page 120

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## Technical sessions

from page 119

comprehensive listing of high speed instruments.

Experimental transient response of a pilot-plant distillation column, M. P. Baber, L. L. Edwards, Jr., W. T. Harper, Jr., M. D. Witte, & J. A. Gerster, Univ. of Del. Data on five-tray, 2 ft. diameter bubble-cap distillation column with sudden change in composition in reflux stream.

A theoretical study of the dynamics and control of binary distillation, D. W. T. Ripplin & D. E. Lamb, Univ. of Del. A new method of studying transient behavior.

### TECHNICAL SESSION NO. 32—TOXIC PLANT CONSTRUCTION—PART 2

Chairman: L. E. Garono, U.S. Army Chem. Corps Eng. Command.  
Co-chairman: M. G. Ringenberg, U.S. Army Chem. Res. & Devel. Labs.

Some requirements for housing, ventilating, and certain service systems for a toxic biological facility, G. R. Holt, Jr., U.S. Army Chem. Corps. Design of utilities and handling techniques.

Engineering safety in the design of toxic chemical plants, J. W. Kenney, U.S. Army Chem. Corps. Evaluation of safety features in design of a nerve gas plant.

Engineering safety in the design of toxic filling plants, W. B. Keene & M. G. Ringenberg, U.S. Army Chem. Res. & Devel. Labs. Safety is 5% inspiration and 95% stickings rigorously to well-known rules.

Construction and operation of toxic chemical pilot plants, B. A. Hildebrand & O. T. Woodward, U.S. Army Chem. Res. & Devel. Labs. Operational techniques, personnel protection devices, toxic waste disposal.

Corrosion problems in a nerve gas plant, L. W. Bonfield, U.S. Army Chem. Corps. Effects of corrosion on metals, alloys, plastics, and coatings.

Corrosion inhibitors and coatings for toxic biological facilities, T. E. Shook & G. R. Holt, Jr., U.S. Army Chem. Corps. Materials used in fabrication and maintenance.

Disposal of by-product HCl from toxic agent plants and the development of a method of disposal, N. P. Cochran & D. A. Falck, U.S. Army Chem. Corps. An account of recent progress.

### TECHNICAL SESSION NO. 33—THE ROLE OF THE CHEMICAL ENGINEER IN ENVIRONMENTAL HEALTH ENGINEERING—PART 2

Chairman: W. L. Faith, Air Pollution Found. Water supply, R. A. Morgen, Rose Polytech. Inst. Conservation and recovery of fresh water supplies.

Water pollution, K. S. Watson, G. E. Role of the chemical engineer in the waste treatment field.

Air pollution, L. B. Hitchcock, Lauren B. Hitchcock Assoc. The chemical engineer is trained to diagnose processing problems and to design corrective equipment.

Food pollution, C. O. Chichester, Univ. of Calif. Expansion of safeguards is needed. Occupational health, S. C. Kyle, TVA. The role of the chemical engineer.

Radiation protection, W. B. Harris, AEC. Discussion of the basic processes in which the chemical engineer is involved.

### TECHNICAL SESSION NO. 34—FLUID DYNAMICS

Chairman: A. Acrivos, Univ. of Calif.

Initiation of roll waves, T. J. Hanratty & A. Hershman, Univ. of Ill. Jefferys' theory applied to flows on vertical walls and to occurrence of flow of gas and liquid.

Plane turbulent wall jet, W. H. Schwarz & W. T. Cosart, Stanford Univ. Velocity distribution of the incompressible, turbulent, plane wall jet.

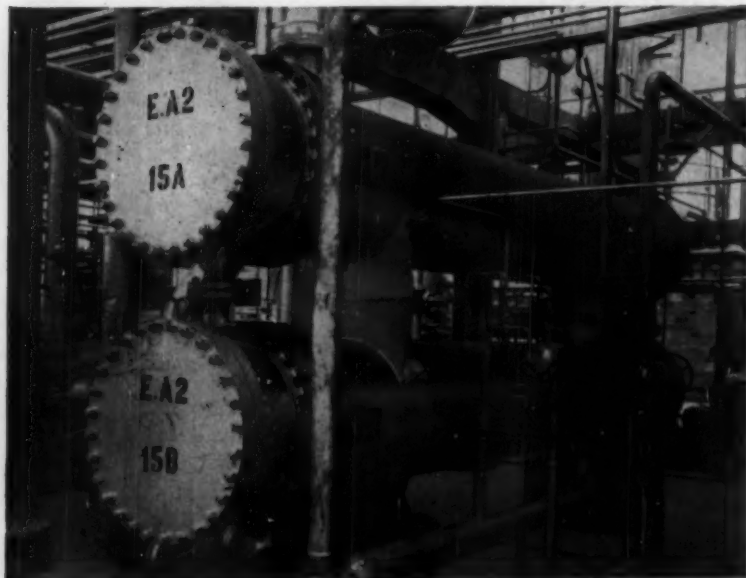
Maximum stable drop size in turbulent flow, C. A. Eichler, Jr., Shell Development. Determination of largest drop that is stable in the turbulent flow of two immiscible liquids in a pipe.

Fundamental theory of fluid-particle systems at low Reynolds Numbers, H. Brenner, New York Univ. The relationship between the drag on a small spherical particle and the permanent pressure drop due to its presence in an infinitely wide cylindrical tube containing a flowing fluid.

Taylor instability of an evaporating plane interface, S. G. Bankoff, Northwestern Univ. The stabilizing effect of evaporation from an interface.

Transient gas flow in porous media—the pressure decay process, E. Weger & D. A. Greenberg, Johns Hopkins Univ. Study of the pressure decay process in porous sintered metal plugs.

Approximate solution for creeping flow in complex geometries: flow across banks of tubes, P. J. Friedl, IBM & K. J. Bell, Case Inst. of Tech. An analog technique for prediction of friction losses.



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More than 30 million gallons of benzene will be produced annually at Mobil Chemical's new plant at Beaumont, Texas. Part of an expanding chemical complex of the company, the facility will also turn out toluene. Scheduled beginning date is early 1962.

A new doctoral program in chemical engineering will be offered at Newark College of Engineering. Authority has been granted by the State Board of Education to confer the degree of Doctor of Engineering Science in chemical, and electrical engineering only.

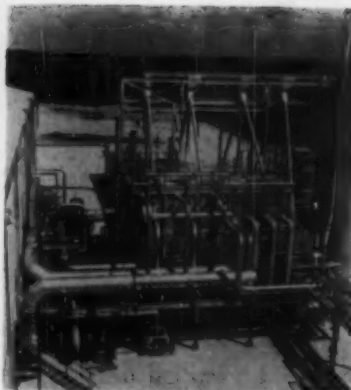
## industrial news

### Liquid hydrogen capacity revealed

Air Products and ARDC plant in Florida Everglades, last of three new units, is one of largest liquid hydrogen plants in country.

PRODUCTION CAPACITY of one of the largest liquid hydrogen plants in the country has just been revealed by U. S. Air Force declassification. The plant can produce liquid hydrogen at the rate of 60,000 pounds a day, far in excess of most previously known liquid hydrogen production units. Built and operated by Air Products, it is located in the Everglades in West Palm Beach, Fla.

The secret liquid hydrogen program was started in 1956 by Air Products and the Air Research & Development Command. At that time, the first production unit in Painesville, Ohio, went on stream with 1500 pounds a day capacity of high energy, ultra-cold liquid hydrogen. Before the Ohio facility went on stream, a second plant with 7000 pounds a day capacity was begun. In 1957, before the second one was completed, the company started construction of the last and largest plant. This went on stream in



The cold boxes at the Air Force's Florida liquid hydrogen plant.

early 1959, with its capacity a well kept secret.

The three plants were referred to as the Bear Series. The large one was Papa Bear, and the medium and small plants were Mama Bear and Baby Bear respectively. Papa Bear and Mama Bear are both located in the Florida Everglades.

The entire program was kept under wraps until mid 1959 when General Bernard A. Schriever, Commander of ARDC, revealed the existence of the liquid hydrogen production facilities. Until now, however, the capacity of the plants was not made known, although estimates of Papa Bear capacity by industry observers ranged up to 30,000 pounds a day—a low guess. #

### Computer control system in West Germany

West Germany's second largest chemical company, Badische Anilin-und-Fabrik AG, will install an RW-300, one of the first closed loop computer control systems outside the U.S.

A major chemical processing unit in West Germany will install one of the first closed-loop computer control systems outside the United States. Badische Anilin-und-Fabrik AG (BASF), West Germany's second largest chemical company, will install the RW-300 Thompson Ramo Wooldridge Digital Control Computer this year at its plant at Ludwigshafen am Rhein. TRW computer engineers have been working with BASF technical personnel for nearly a year, analyzing the process and developing the computer control system.

Officers of the company anticipate increased product yield and through-

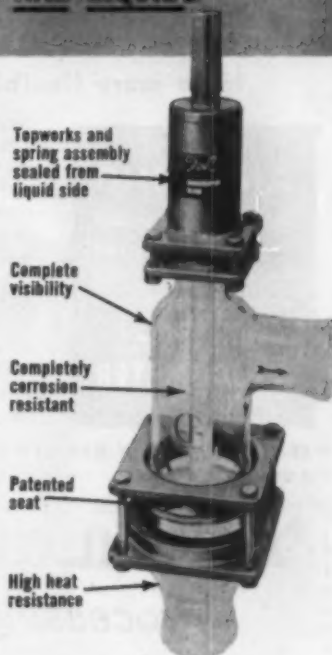
put of the unit in a substantial amount. Improved quality control, more accurate and comprehensive operating data, with less risk of process upset are also anticipated. The German chemical company decision to install the system was based on the necessity at the plant for a field proved system specifically engineered for process control.

The computer controls the process by reading instruments in the plant, by performing computations based on information received and on the mathematical model stored in the computer's 8000 work memory unit. Included in the transistorized digital computer is a desk-size computer, an operator's console, an automatic input-output typewriter, and an automatic data logging typewriter.

Recently, two leading French electronic firms, Compagnie Generale de Telegraphie Sans Fil, and Intertechnique, formed a subsidiary, Compagnie Europeenne d'Automatisme Electronique, to manufacture and market the RW-300's for the European market. #

# NEW

A "SEE-THROUGH"  
SAFETY-RELIEF VALVE  
THAT SEALS GASES  
AND LIQUIDS



A completely new concept in relief valve seat design plus Pyrex & Teflon Construction for the added advantages of full visibility and corrosion resistance. Seat pressure is completely independent of spring load. Valve reseats after venting without labor or material cost of rupture disc replacement. Ideally suited for both pressure and vacuum relief. Seals against liquids and gases. Use with liquid lines, with reactors and vessels of all types. Available in other materials of construction. Ask us for Bulletin RV-1.

\*T.M., Corning Glass Works

### A NEW LINE OF CORROSION RESISTANT FILTERS

Permanent filter element offers maximum particle retention with very high flow rate. Porosity range, one to 100 microns. Use for sterilization, clarifying, polishing. Pyrex & Teflon construction for visibility and high temperature applications. Write for Bulletin FFI-2.



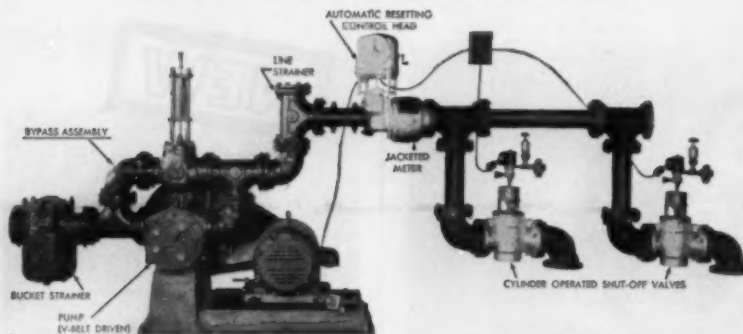
**CHEM FLOW CORP.**

187 Paterson Avenue  
Little Falls, N. J.

For more information, circle No. 42



For more information, turn to Data Service card, circle No. 10



## TYPICAL MULTI-VALVE FLUIDOMETER SYSTEM for a more flexible production schedule

### ANYTHING

that can be handled  
through a meter can  
be accurately and  
economically batched  
by the

### FLUIDOMETER

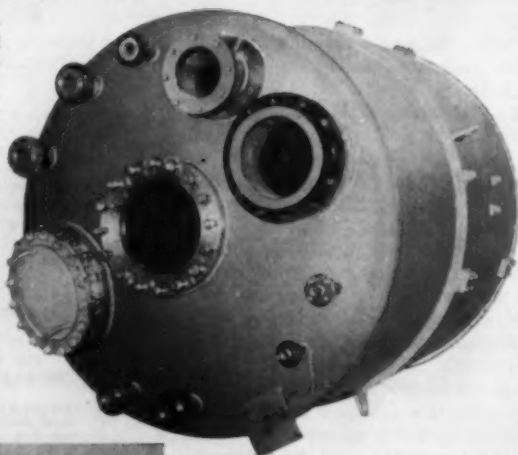
Multi-Valve Fluidometer systems make possible a more flexible production schedule by varying the size of the batches, or by using the automatic resetting control to deliver the same quantity time after time. A multi-valve Fluidometer system may be controlled either at the point of use or at the Fluidometer control head. Fluidometer installations are available either jacketed or un-jacketed and are "tailor made" to fit the particular job. Tell us your batching problem and let us give you our suggestions for solving it.

Bulletin FI-56 will be sent on request. For information on jacketed pipe and fittings write for Bulletin J-56.

**HETHERINGTON & BERNER INC. • ENGINEERS-MANUFACTURERS**  
710 KENTUCKY AVENUE INDIANAPOLIS 7, INDIANA

## BETHLEHEM..... Processing KETTLES

During the past 50 years, Bethlehem's engineering experience has built unsurpassed know-how and efficiency in building processing kettles. They have been used in the following capacities: Corrosive Service... such as sulphonations, nitrations, reductions. Direct Fired Operations, such as caustic fusions and sodium bi-sulphate manufacture. Heavy Duty Needs, such as processing extremely viscous and pasty materials. Handling Abrasive Solids, especially in the reaction.



See 8-page catalog in C. E. C.  
for complete facilities of

Process Equipment Division of

**BETHLEHEM FOUNDRY  
& MACHINE CO.**

BETHLEHEM, PENNA.

BETHLEHEM manufactures kettles in cast metals and fabricated steel, stainless steels, alloys, and clad; to ASME Code, other specifications and company standards. X-ray and other test techniques assure sound construction for demanding service.

WRITE FOR BULLETIN 600 to learn more about BETHLEHEM processing kettles for reaction, agitation, heat transfer, distillation, sublimation, crystallization, drying.

For more information, turn to Data Service card, circle No. 112

## local sections

## Officers for the coming year

Officers in the local sections elected  
for 1960-61 are:

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Vice chairman	J. A. Glass
Secretary	R. J. Pikna
Treasurer	R. L. Miller

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Vice chairman	D. A. Hermanson
Secretary	J. J. Leonard
Treasurer	J. G. Huddle

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Secretary	L. M. Wylie

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Vice chairman	R. E. Sattler
Secretary	S. J. Marwil
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Vice chairman	J. B. Bingeman
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Vice chairman	W. H. Tell
Secretary-Treas.	J. B. O'Hara

### Central Ohio Section

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Vice chairman	J. H. Oxley
Secretary-Treas.	A. W. Lemmon, Jr.

### Central Oklahoma Section

Chairman	J. B. West
Vice chairman	C. C. Schierman
Secretary-Treas.	W. C. Galegar

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Vice chairman	R. E. Slonaker, Jr.
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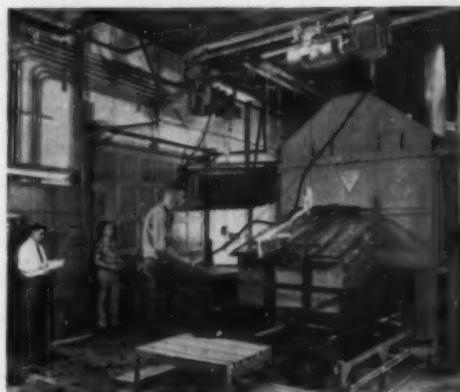
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*continued on page 124*

## NEW DESPATCH FURNACE USED TO PRODUCE REVOLUTIONARY BATTERY



**Twin City  
 Manufacturer  
 Makes New  
 Electrodes  
 With Secret  
 Heat Process**

A specially designed new high-temperature Despatch furnace is helping a St. Paul firm produce a revolutionary sealed and rechargeable nickel-cadmium battery. Details of performance are still confidential, but officials of Nicad Sealed Cell Division, Gould-National Batteries, Inc., report results are "very satisfactory."

Electrically heated, the furnace is electronically controlled, has a pneumatically operated vertical-lift door, and is lined with special steel. Processing "thousands per hour" of special electrodes produces corrosive gases which would destroy conventional ovens, the firm stated.

Despatch was chosen to produce the furnace because of "good success" the company has had with previous Despatch installations. Company officials praised performance, economy of operation and durability.

Despatch engineers can solve your firm's special problems too. Take advantage of the skills developed from tens of thousands of industrial installations. Write *today!* for free bulletin 100BB.

**DESPATCH—INDUSTRY LEADERS FOR 58 YEARS**

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from page 123

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A Japanese firm will manufacture the Swartwout's electronic process instrumentation line, under a recent technical assistance contract. Facilities are now under construction for Ohkura Electric Co. to make recording indicating and controlling instruments and accessory products, and Autronic measuring line. The Japanese firm has been sales and service agents for Swartwout in Japan for several years.

A \$1,500,000 plant to manufacture phosphoric acid for high analysis fertilizer will be built by Olin Mathieson. Capacity of the Joliet, Ill. plant will be approximately 50,000 tons a year of 75% concentrate. Production is slated for fertilizer manufacturers in the midwest. The facility, scheduled to be completed by the end of April, 1961, is part of a \$30 million expansion program by the company.

Construction of plant facilities to produce butanols is underway at Dow Badische Chemical. Freeport, Texas. N-butanol and iso-butanol products of the plant, will be sold through Dow Chemical Co. A 60% expansion in the benzene plant of Enjay Chemical at Baton Rouge, La. will increase capacity from 15 to 24 million gallons per year by the end of 1960, it is estimated.

## FLUID & GAS PRESSURE TANKS STAINLESS & CARBON STEEL TANKS

### (GOVERNMENT SURPLUS BARGAINS)

Steel tanks for the handling, storage and transportation of gases, beverages, fuels, hydraulic fluids and other liquids. Stainless steel tanks for corrosive acids and gases.



**J-1 PRESSURE TANK** Stainless steel, surplus aircraft oxygen tank, 48" long, 24" dia. Rated for 400 P.S.I. working pressure, 18,000 cu. in. vol., 77.9 gal. capacity, 1/2" pipe thread fitting at each end. New condition. Shipping weight 247 lbs. F.O.B. Chicago. No. AD832.....\$99<sup>95</sup>

**G-1 TANK** Stainless steel. Capacity 2100 cu. in. (9 gals.) 450 P.S.I. 1/2" pipe thread port at each end, 24" long, 12" dia. Shipping weight 19 lbs. F.O.B. Chicago. (Two for \$27.00.) No. AD83.....\$14<sup>95</sup>

**NON-SHATTERABLE CO<sub>2</sub> CYLINDER** This type of pressure bottle was used by the Armed Forces for inflating life rafts. 18 1/2" long, 3 1/2" dia. Has 1/2" pipe thread opening at one end. Capacity 2.98 lbs. of CO<sub>2</sub>—at 1800 P.S.I. Shipping weight 10 lbs. F.O.B. Chicago. No. AD303.....\$2<sup>50</sup>

**FREON TANK** Capacity 22 oz. of Freon F22, 6 cc Methyl Alcohol. 18 1/2" long, 2" dia. 1/2" pipe thread opening at one end. Equipped with brass valve. Shipping weight 3 lbs. F.O.B. Chicago. (Six for \$8.00). No. AD834 Each.....\$1<sup>50</sup>

**D-2 AIR TANK** Carbon steel. Capacity 500 cu. in. (approx. 2 gals.) 450 P.S.I. 1/2" pipe thread port at each end, 24" long, 6" dia. Postpaid. (Two for \$8.50). No. AD391 Each.....\$4<sup>95</sup>

**CORNELIUS HIGH PRESSURE (1500-2000 P.S.I.) AIR COMPRESSOR** Three cylinder, 3-stage compressor, complete with 27 volt, D.C. 20 amp. motor, with fan. Rated 1500 P.S.I. intermittent duty, 2000 P.S.I. intermittent. Pressure switch in base. As released by Air Force, in used, serviceable condition. Covered by our 30 day GUARANTEE. 11 1/2" long, 7" high, 9" wide. Shipping weight 12 lbs. F.O.B. Chicago. Limited quantity. No. AD549.....\$35<sup>95</sup>

Write today for FREE CATALOG of other EQUIPMENT BARGAINS!

## GROBAN SUPPLY COMPANY

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## NEW FROM H & T Low-Cost • High-Performance "PACKAGE" DEMINERALIZERS!

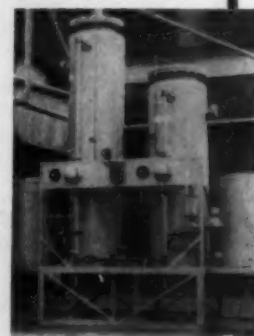
TWO BED & UN-A-BED  
STANDARD UNITS  
**NOW  
AVAILABLE!**

Unless special conditions require you to use a special demineralizing system, you can save big money—and get excellent results with the new H&T Standard "PACKAGE" DEMINERALIZER! Into these superior Standard Units, we've put the experience of 16 years in building many hundreds of manual and automatic demineralizing systems. Result: H&T "PACKAGE" DEMINERALIZERS are masterpieces of design and construction—unequalled in performance and wonderfully low in cost.

Write for details of Two-Bed  
and Un-A-Bed Demineralizers

**HUNGERFORD & TERRY, INC.**

CLAYTON 10, NEW JERSEY



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CHEMICAL ENGINEERING PROGRESS, (Vol. 54, No. 10)

## A.I.Ch.E. Candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive carefully consideration if received before November 15, 1960, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

### Member

Anderson, John R., Tarrytown, N. Y.  
Atteridge, Paul T., New York, N. Y.  
Barry, Lewis A., Butler, Pa.  
Belcher, Donald W., North Branch, N. J.  
Berglund, William K., Fernandina, Fla.  
Blanchard, T. R., Bridgeville, Pa.  
Block, Frank E., Albany, Oregon  
Blumberg, Ruth, Haifa, Israel  
Brugmann, Lawrence E., Garden Grove, Calif.  
Bruner, Chester A., Kingsport, Tenn.  
Burlison, Carl B., Lake Jackson, Texas  
Buttery, L. M., Texas City, Texas  
Carnesale, Mario J., New York, N. Y.  
Chao, Kwang-Chu, Richmond, Calif.  
Claypool, Jay Gene, Whittier, Calif.  
Currie, R. M., Florence, S. C.  
DeGross, J. H., Memphis, Tenn.  
Deutch, Michael J., Washington, D. C.  
Driscoll, John M., New York, N. Y.  
Elliot, Arthur M., Orange, Texas  
Farrell, Joseph B., Westport, Conn.  
Harehman, Richard C., Grand Island, N. Y.  
Hoffman, Dwight S., Moscow, Idaho  
Holman, John L., Minneapolis, Minn.  
Horn, Walter R., Joplin, Mo.  
Jones, Robert E., Charlotte, N. C.  
Kennedy, Robert M., Marcus Hook, Pa.  
Kessler, Nat., Decatur, Ill.  
Kingman, Kenneth E., Los Angeles, Calif.  
Mockridge, Oscar A., Jr., Montclair, N. J.  
Moore, Raymond H., Richland, Washington  
Nevius, Richard R., E. Brunswick, N. J.  
Newberry, James R., Tonawanda, N. Y.  
Pennington, R. E., Dayton, Texas  
Frongle, Robert S., Circleville, Ohio  
Pribush, Adolf J., Linden, N. J.  
Rohrman, F. A., Panama City, Fla.  
Romling, Charles, Jr., Tomaco, N. J.  
Roth, Ernest R., Media, Pa.  
Rowland, O. B., Jr., Bastrop, La.  
Sarkisian, Arthur, Cranford, N. J.  
Siegfried, Robert E., Cambridge, Mass.  
Simpson, James F., Columbus, Ohio  
Smith, Anthony J., New York, N. Y.  
Smith, William C., Iron Mountain, Mich.  
Stones, Frank W., Cambridge, Mass.  
Tackett, Thomas N., III, Texas City, Texas  
Tarr, Donald T., Jr., San Leandro, Calif.  
Taylor, Jess G., Seaside, Maine  
Thatcher, Charles M., Manhasset, N. Y.  
Van Cor, Frederick B., So. Branch, N. J.  
Vandegrift, Robert A., Boulder, Colo.  
Wallentine, Ervin W., Port Arthur, Texas  
Weatherly, David M., Atlanta, Ga.  
Woodie, Robert A., Port Arthur, Texas  
Zwolinski, J., Zionville, Pa.

### Associate member

Aiba, Shuichi, Tokyo, Japan  
Allen, Wickham, New South Wales, Australia  
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Ballard, George A., Oakland, Calif.  
Barnett, Hugh D., Macapeth, N. Y.  
Beale, John S., Jr., Midland, Mich.  
Beckmann, Rudolph A., Baton Rouge, La.  
Binder, Robert E., Irvington, N. Y.  
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Blotner, Malcolm R., New Brunswick, N. J.  
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Cheslov, Richard T., Grand Island, N. Y.  
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Conlin, Mary A., Brookline, Mass.  
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Dunne, Arthur J., Wyandotte, Mich.  
Duston, Frank A., Springfield, Mass.  
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English, K. Gayle, Longview, Texas  
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Fahrentbold, Paul, Houston, Texas  
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Hanes, Donald J., Nixon, Texas  
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Hemphill, Paul D., Bishop, Texas  
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Hodous, Ralph J., Shaker Heights, Ohio  
Hoffman, Alfred A., Jr., Bartlesville, Okla.  
Hsu, Hsien-Wen, W. Lafayette, Ind.  
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Jones, David L., Athens, Ohio  
Kagetan, Tadaaki Jack, Niagara Falls, N. Y.  
Kane, Richard G., Springfield, Mass.  
Kerr, Gerald E., St. Louis, Mo.  
Kruschler, Joseph J., Princeton, N. J.  
Krigans, Arnie G., Salem, Oregon  
Kulkarni, B. D., Bihari, India  
Lee, Roy C., Delaware, Ohio  
Leigh, W. R. D., Sydney, Australia  
Lowry, Loren R., Whittier, Calif.  
Matthews, Lewis G., New York, N. Y.  
Mayer, Francis X., Baton Rouge, La.  
McAtee, Phillip J., Cincinnati, Ohio  
McCarty, Charles H., Jr., Charlottesville, Va.  
McGinnis, Paul H., Jr., Raleigh, N. C.  
McHane, Vern R., Southgate, Mich.  
Meredith, Nelson B., Baltimore, Md.  
Merry, Donald H., Kirkwood, Mo.  
Miller, George R., Freeport, Texas  
Milmo, Jose, Mexico D. F., Mexico  
Moore, L. Dow, Nashville, Tenn.  
Morgan, James I., New York, N. Y.  
Morrow, Tommy, Pasadena, Texas  
Mostoufi, Feraldeen, Borger, Texas  
Musselman, Ned H., Portsmouth, Ohio  
Myers, John A., Lawrence, Kansas  
Mylius, Herbert Walter, Wilmington, Del.  
Neel, Joseph C., Wilmington, Del.  
Nelson, R. E., Bloomfield, N. J.  
Nester, James F., Middleport, Ohio  
Oates, Kenneth L., Youngstown, Ohio  
O'Dette, Ralph E., Rockville, Md.  
Omer, Mir M., Edmonton, Alta., Canada  
Ord, James N., Palmerton, Pa.  
Parikh, Shirish M., New York, N. Y.  
Patel, Nanoo M., Los Angeles, Calif.  
Pekarsky, Stanley J., Bronx, N. Y.  
Peltzman, William S., Alhambra, Calif.  
Perkins, Richard A., Mt. Gilead, Ohio  
Pike, Ralph W., Jr., Athens, Ga.  
Pooley, Thomas R., Fair Oaks, Calif.  
Pulios, George J., Minneapolis, Minn.  
Rankin, John A., Wilmington, Del.  
Ray, Harry F., Belleville, Ill.  
Reeds, J. Nelson, Terry, Haute, Ind.  
Robinson, Ralph Duane, Shelby, N. C.  
Rogers, Olsen J., Los Angeles, Calif.  
Robde, Howard James, San Francisco, Calif.  
Ruggieri, Peter W., Jr., Vienna, W. Va.  
Safra, Jack Alan, Los Angeles, Calif.  
Salame, Morris, Hartford, Conn.  
Santiago-Ruis, Felix D., Mayaguez, Puerto Rico  
Sarem, Amir M., Tulsa, Okla.  
Scher, Marvin, Syracuse, N. Y.  
Sevigny, Rene, Jr., Rochester, N. Y.  
Siegman, Edwin J., So. Euclid, Ohio  
Sierra, Homer E., Salamanca, Mexico  
Slaughter, J. A., Jr., Memphis, Tenn.  
Snook, John, Jr., Bound Brook, N. J.  
Spicer, William E., Knoxville, Tenn.  
Spuriock, Jack M., Tucker, Ga.  
Stannard, Frank L., Akron, Ohio  
Tayyabkhan, M. T., New York, N. Y.  
Trensen, William J., St. Paul, Minn.  
Wang, Chen-Shen, Chicago, Ill.  
Webster, James H., St. Paul, Minn.  
Weber, Charles C., Jr., Richland, Wash.  
Wilson, Riley Woodrow, Jr., Baton Rouge, La.  
Withrow, James L., LaRue, Ohio  
Zippich, Charles F., Minneapolis, Minn.

### Affiliate grade

Bentley, Ellis B., League City, Texas  
Berenso, P. J., Santa Monica, Calif.  
Currie, F. Rigdon, Houston, Texas  
Dupree, Lansing T., W. Islip, N. Y.  
Hunter, John S., Madison, Wisc.  
Makens, Royal F., Houghton, Mich.  
Schumacher, Willard A., Elkhart, Ind.  
Sandberg, Lee E., Charleston, W. Va.  
White, Donald G., Monroeville, Pa.



## LANDSVERK MODEL L-75D ISOTOPE ANALYSIS UNIT

The Isotope Analysis Unit is a sensitive, accurate ionization chamber instrument for measurement of alpha, beta or gamma radiation. It features simple, reliable operation and low maintenance cost. Widely accepted by A.E.C. laboratories, it is also used extensively in the A.E.C. teacher training program.

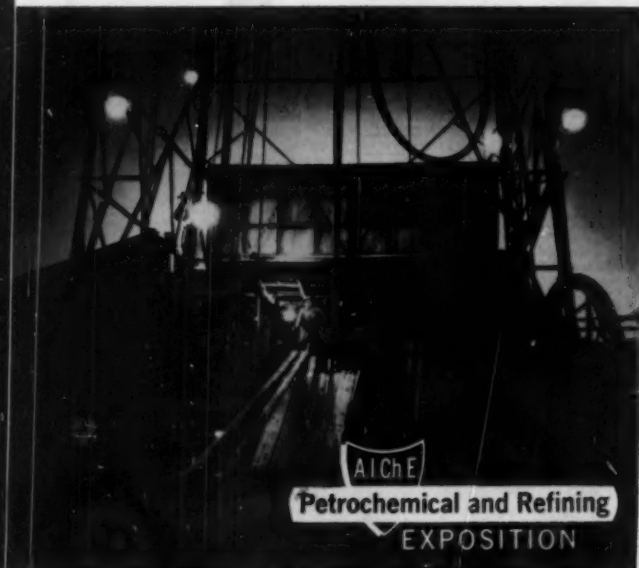
Model L-75K is the kit form which includes sample trays, planchets, filters, light source, special holders.



**Landsverk  
Electrometer  
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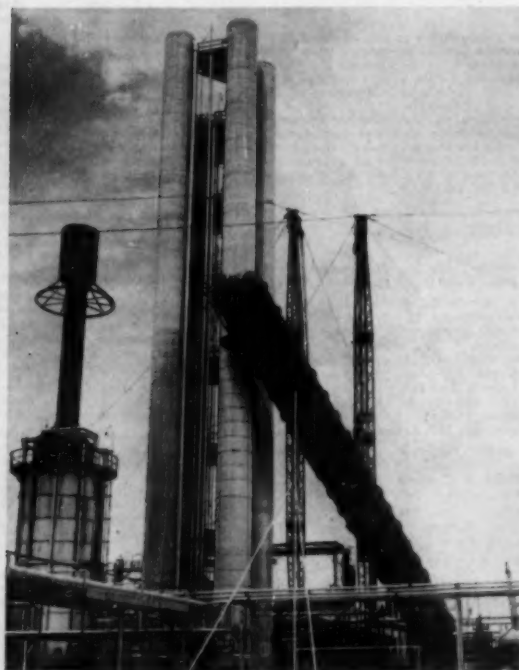
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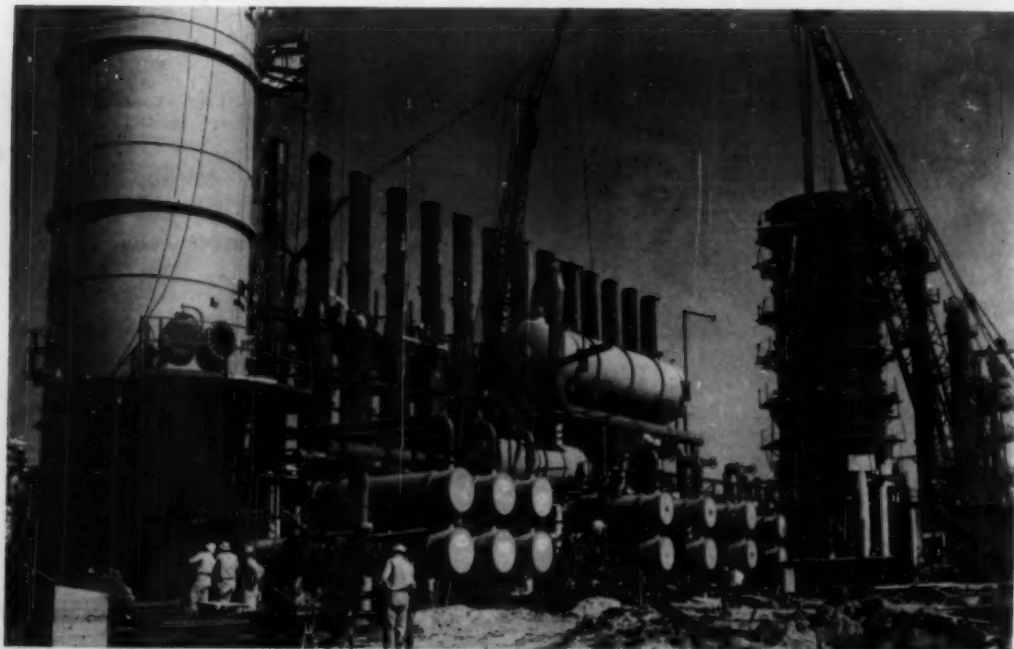


## Petrochemicals in focus

Oil and gas wells serve as the source of all petrochemicals. The entire petrochemical story from source to end products will be told in New Orleans, February 26-March 1, when the A.I.Ch.E. holds its first Petrochemical and Petroleum Refining Exposition in conjunction with its 44th National Meeting.

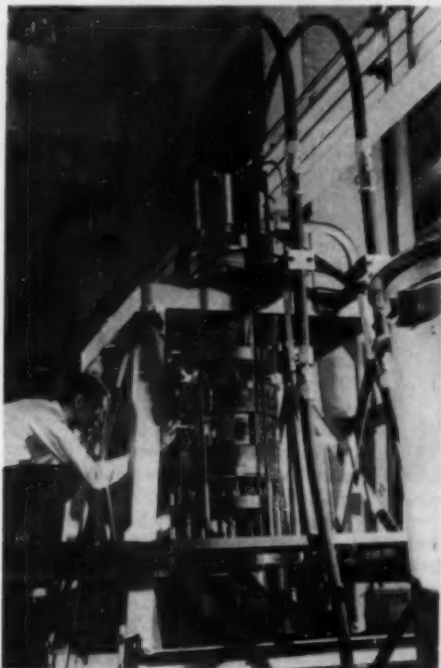


THIS 159 FT. STYRENE RECOVERY COLUMN being erected at Cosden Petroleum's Big Spring, Texas, refinery, marks the beginning of the final third of the company's expansion of styrene capacity to 70 million pounds a year.



WORLD'S LARGEST ETHYLENE UNIT being built by Mobil Chemical Co. at Beaumont, Texas. Scheduled for completion next year, the unit will supply neighboring plants of Goodyear Tire & Rubber and Houston Chemical.





A NEW HIGH-ENERGY electric arc heater may find important applications in chemical processing, according to Westinghouse Electric, who hope to offer the equipment commercially within two years. The machine, says the company, has the potential capability of supplying a continuous stream of gas at temperatures to 20,000°F and pressures up to 15,000 lb./sq. in. Maximum contamination level of the gas is 0.2%.



LONGEST SINGLE PIECE OF GRAPHITE for its cross-section ever made is this 30-ft. column measuring 12 by 14 in. on the sides. Made by National Carbon Co., the block weighs 3700 pounds.



REACTOR IN NATION'S LARGEST atomic power plant went critical recently at Rowe, Mass. Yankee Atomic Electric's plant is the first nuclear-powered station in New England.



UNITED ENGINEERING BUILDING rises above New York's East Side. Open park of the UN frames building against New York's skyline.

people  
in management  
and technology

## Whitman, Whitaker, honored by Institute

W. G. Whitman and M. C. Whitaker have been chosen to receive the A.I.Ch.E. Founders Award for 1960. Whitman (right) recently took leave from his post as head of the Dept. of Chemical Engineering at MIT to accept an assignment in the State Department. Whitaker, retired director and vice president of American Cyanamid, was president of A.I.Ch.E. in 1914.

Whitaker's distinguished career, both in academic circles and in industry, started in 1896 when he became an instructor in Applied Chemistry. During his tenure as Professor of Chemical Engineering at Columbia University, he inaugurated Columbia's first independent department of chemical engineering. As a top officer of American Cyanamid, he was largely responsible for consolidating that firm's research program into one of the largest in the country. After retiring



in 1947, he functioned as consultant to the company.

Among patents held by Whitaker are ones on processes for distillation, removing nickel from hydrogenized fat or oil, and treating resinous woods. He is the author of many technical papers.

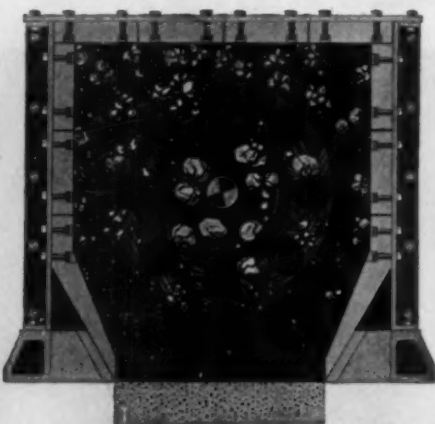
Honors received by Whitaker are the Perkins Medal, 1923, the Columbia University Medal for Excellence, 1950, and Columbia's Chandler Medal, 1951. A director of ACS from 1931-36, he has held top offices in the Chemists' Club and the Society of the Chemical Industry, in addition to early work in A.I.Ch.E. He holds honorary degrees from the University of Colorado, (LLD) and the University of Pittsburgh, (PhD in Chemistry.)

Whitman, who recently took over as science adviser to the Secretary of State, (see CEP September, 1960, p. 146) is widely known as an educator and leader of research. He has been head of the Department of Chemical Engineering at MIT since 1934. Whitman was president of A.I.Ch.E. in 1956, and is a member of ACS and an honorary member of the American Institute of Chemists.

He was first to appreciate the extent to which diffusion processes control in the fields of corrosion and absorption of gases by liquids. He has published papers in the fields of petroleum refining, heat transfer, physical properties of petroleum and its conservation.

Presentation of the Award will be made at the Annual A.I.Ch.E. meeting

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For more information, turn to Data Service card, circle No. 25

in December, in Washington, D.C.

**Osgood V. Tracy** has been elected a director and executive vice president, **W. R. Grace & Co.** Formerly president, **Esso Standard**, (Humble Oil & Refining), he will be



in charge of the chemical business of the company. Tracy will also be responsible for the seven operating divisions, as well as the Research Division making up the Grace Chemical Group. He was with Esso Standard for thirty years, except for a period in 1951-52, during the Korean War. Then, he was the first oil-industry representative to hold the post of Director of the Chemical Division, National Production Authority.

**H. E. Hoelscher**, professor and chairman of the Chemical Engineering Department at Johns Hopkins, has returned after a year in India on a UNESCO assignment to the University of Madras. **S. K. Friedlander**, associate professor of Chemical Engineering at the University, has been awarded a Fulbright grant for study and research in France during the coming academic year. Friedlander will be attached to

the Laboratoire d'Aerothermique, doing work in the field of nucleation and condensation in flowing gases. Other appointments in the Department are: **J. F. Wehner**, assistant professor, and **R. M. Fristrom**, part time lecturer. Fristrom is on the principal staff of the Johns Hopkins applied physics laboratory.

**John Shacter** has been appointed manager, planning, Union Carbide, moving up from the post of assistant manager. Shacter is also a lecturer in chemical engineering at N.Y.U. He has served as consultant to AEC and to the Department of Defense.

**Willard A. Schumacher** has been appointed general manager, American operations, for the LaBour Co. Schumacher joined the Elkhart, Indiana, company in 1952



as sales manager, and later became vice president and a director. He will continue in these capacities. He has been working in the field of pump manufacturing for chemical process industries for thirty years.

**C. A. Butler** has joined **R. B. MacMullin Associates** as a partner. He will

manage the Cleveland office of the Niagara Falls, N.Y. consulting firm.

In election of top officers at Scientific Design, **Paul S. Monroe** and **Alfred Saffer** were named vice presidents in charge of construction and manufacturing, respectively. Assistant vice presidents are: **Russell G. Hill**, project engineering; **George J. Marlowe**, general engineering; **John H. Lutz**, director of administration and finance; **Gerson S. Schaffel** and **Alfred R. Smith**, new projects; and **Gregory F. Vinci**, operations.

**Arthur Rose**, Pennsylvania State University, has been relieved of his duties as professor of chemical engineering in order that he may direct the revision of the *Condensed Chemical Dictionary and Distillation Literature Index and Abstracts*. He will also engage more fully in work at Applied Science Laboratories. Rose will continue the direction of his graduate research program at the University.

One of the newly elected officers of the American Section, Society of Chemical Industry, is **Robert W. Cairns**, Hercules Powder. Members of the executive committee are: **D. B. Benedict**, Union Carbide; **H. K. Nason**, Monsanto; **H. I. Cramer**, Penn-

*continued on page 130*

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### GEAR PUMP OPERATES

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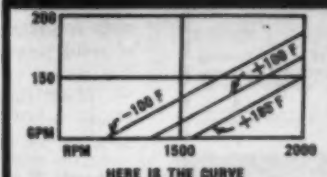
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October 1960 129





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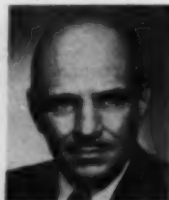
ADDRESS \_\_\_\_\_

For more information, circle No. 79

## people

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salt Chemical; Cecil W. Humphreys, Shell Chemical; Carl F. Prutton, Food Machinery and Chemical; and F. K. Schoenfeld, B. F. Goodrich.



Three college professors served as consultants and worked the past summer at Humble Oil & Refining's Baytown, Texas plant. They are: J. E. Powers, chairman of the school of Chemical Engineering at U. of Oklahoma; Harold Graham, Vanderbilt U. and R. E. Glick, Chemistry Department, Florida State U.

At the Humble Research and Development Division, Baytown, Texas, H. E. Cier (above) was promoted to senior research specialist. He is now serving on a rotational assignment in the Technical Division. H. A. Holcomb has been promoted to section head, Research and Development Division, Humble Oil & Refining's Humble Division. He heads the group at the Baytown, Texas, plant, engaged in chemicals development research.

John W. Corey heads the Ludington Division, Dow Chemical. He was formerly director, research and development laboratory at Ludington, and in charge of Type B Catalyst production there since 1958. With Dow since 1924, Corey holds a number of patents on fertilizers and catalysts, and has done considerable research on brine and cell feed processes. Corey is a former chairman of the Midland Section, A.I.Ch.E.

Morton Harloe has joined Technicon Controls, Inc., as field applications engineer. He will work on developing research and onstream applications of the Technicon Auto-Analyzer automatic continuous chemical analysis.

J. Norman Rossen has been appointed director, Solid Propellant Division, Atlantic Research. He will be responsible for manufacture and processing of solid propellants and solid propellant rocket testing at the Gainesville, Va. plant. Rossen succeeds Presson S. Shane, who was elected vice president earlier this year.

Richard N. Meier has joined the Lafayette College Chemical Engineering Department on a part-time basis. Meier is a research engineer with Air Products, Allentown, Pa.

Karl A. Muller has been promoted to

senior chemical engineer, process development laboratories, American Oil.

Manford R. Haxton moves up to the post of chemical engineer, (group leader) at the Texas City refinery of the company.

Clifford C. Taylor, Jr. has been named project manager, Brazilian operations, for Koppers. Taylor recently returned from several years in South America. He worked as plant manager at Companhia Brasileira de Estireno, a styrene monomer firm in which Koppers has a substantial interest.

John M. Sharf spoke

before the International Symposium on Food Microbiology at Evian, France, in September. He delivered a paper on Evolution of Microbiological Standards for Bottled Carbonated Beverages in the U.S. Sharf, general manager, packaging materials research, Armstrong Cork Research and Development Center, has been with the company since 1942. He specializes in research in the packaging of foods and beverages in glass containers.



W. H. Honstead will head the Kansas State University Chemical Engineering Department. He had been acting department head since last spring. Honstead is also associate dean of the School of Engineering and Architecture.

Carl F. Prutton has been elected to the Board of Directors, Commercial Solvents Corp. He is a director of Food Machinery and Chemical, and a consultant for several chemical companies. Prutton retired recently as executive vice president, Chemical Divisions, Food Machinery and Chemical.



John F. Harron has been appointed to the Advanced Management and Methods Division, Sun Oil's Manufacturing Department. Harron who has been with Sun since 1928, will have headquarters in Marcus Hook, Pa. Appointed manager, the Toledo refinery to replace Harron is Herbert C. Thober (above), who joined the company in 1941, was superintendent of refining, and before that chief chemical engineer. He is one of the founders of the Toledo Section of A.I.Ch.E. Another executive appointment is John F. McKin-



ney, Jr. who takes over as assistant superintendent of the Toledo refinery. James M. Willis was honored by ACS, Rubber Chemistry Division, when he received a certificate for outstanding paper presentation. His report on the compounding and testing of Diene, synthetic rubber extender, was judged the best of those submitted at the spring meeting of the Rubber Chemistry Division at Buffalo, N.Y. Willis is on the research staff of Firestone Tire & Rubber.

Richard G. Bauman has been named manager of tire research, Products Research and Development Department, B. F. Goodrich, Brecksville, Ohio. Formerly a senior scientist in the new Products Department, Bauman has been with the company since 1950. He is scheduled to lecture on tire performance at the Deutsche Kautschuk-Gesellschaft Rubber Conference in West Berlin, and at the Rubber and Plastics Symposium in London this fall.



At B. F. Goodrich, Cleveland, R. Emerson Lynn, Jr. has been named manager, program planning. Lynn is a director of the Akron, Ohio, Council of Engineering and Scientific Societies, and vice chairman of the arrangements committee for the A.I.Ch.E. National Meeting next May in Cleveland.

Chaplin Tyler has received the Award of Merit of AACE for 1960. He received the award for his outstanding contributions to cost engineering economics, analysis and its application to the chemical process industries. Tyler, who is with Du Pont's Development Department, served for three years as lecturer in Economics at the University of Delaware. He was also a consultant in technology to the President's Materials Policy Commission. He is author of *Chemical Engineering Economics* and a contributor to the *Encyclopedia of Chemical Technology*.

Robert R. White has been elected vice president, Atlantic Refining. He has also been appointed general manager, Research and Development Department. White has been serving as director, Institute of Science and Technology, University of Michigan. He was formerly associate dean, College of Engineering, and the Horace H. Rackham School of Graduate Studies at the University.

New President of the American Insti-

tute of Chemists is Milton Harris, who succeeds Wayne E. Kuhn, Texaco, in the post. One of the three newly elected councilors-at-large is Ray P. Dinsmore, vice president, research and development, Goodyear Tire & Rubber.

Edward S. Rothrock, senior vice president of Stauffer Chemical, received the first Distinguished Alumnus Award from Rice Institute for outstanding achievement in the chemical engineering profession. Rothrock, who is also general manager of Stauffer's Consolidated Chemical Industries Division, Houston, Texas, was selected by vote of students and faculty in the Rice Chemical Engineering Department. Presentation was made at the annual dinner of the Rice Institute chapter of A.I.Ch.E.

C. Randall Thomas has been promoted to manager, process engineering section, R&D Department, Texas-U.S. Chemical. Before joining Texas in 1956, he was with Du Pont, Polychemical Department. Thomas was at Texas Research Center in Parsippany, N.J., until last year.

Peter P. Wegener has been appointed to the faculty of Yale University as Professor of Mechanical Engineering. He took over his new post July 1, after returning from a lecture tour of Italy, Belgium and Germany, including several weeks at the University of Munich. Wegener was previously a section chief at the Jet Propulsion Lab, California Institute of Technology.

Silas P. Smith has been appointed to the new post of resident director of Engineering, Union Carbide Chemicals. He moves up from the post of associate director of engineering at the Charleston plant. A. W. Byer moves into the position of assistant director of engineering at the South Charleston, West Va. plant.

J. Harold Perrine has been named assistant director of industrial relations, Sun Oil. Perrine, who joined Sun as a research engineer in 1930, was formerly administrative manager, Research and Engineering Department. He is company representative to the Industrial Research Institute.

Robert H. Rogge takes over the post of assistant to the vice president, administration, Corn Products Co. With the firm since 1944, he was director of engineering, Development Department, until his promotion. Charles A. Wollbach, Jr. has joined Lummus' Newark, N.J. office as pro-

continued on page 132

## NEW Q-SERIES TWO-STAGE Diaphragm Compressors



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### Performance

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These laboratory and pilot plant two-stage compressors have a built in relief valve in each head. The stainless steel heads are water cooled when necessary. Furnished complete with explosionproof motor, belt guard, hydraulic reservoir, interstage pressure gauge and rupture assembly, steel base, pressure gauge, suction and interstage filters and all necessary piping.

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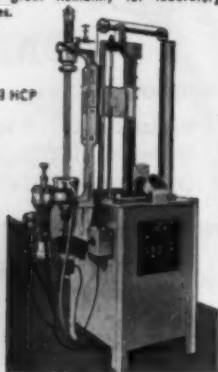
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- Continuous water cooling for the outside of the quartz tube during operation.
- Assembly and dis-assembly of this system including removal of the completed process bar is simple and rapid.

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Spark Gap Converters from 2 Kw to 30 Kw

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## people

from page 131

ject manager. Formerly with Singmaster & Breyer, and National Lead, Wolbach has also done consultant work on filtration, dust collection, drying and titanium dioxide pigment manufacture.

T. H. Chilton left for Japan in August. He will be at the University of Kyoto, in Kyoto, Japan, Department of Chemical Engineering, on a Fulbright Lectureship. Chilton, who received the A.I.Ch.E. Founders Award in 1958, is Institute Lecturer for 1959.

Roy S. Arrandale has been appointed to the advisory board, U. of Rochester, Chemical Engineering Department, for a three year term. Arrandale is vice president and technical director, Thatcher Glass Manufacturing.

A. Arthur Kwapisz joined Pittsburgh Chemical as plant manager of the new activated carbon plant at Catlettsburg, Ky.

Herbert F. Kraemer has joined General Mills as head of the Chemical Engineering Department, Central Research Laboratories. Kraemer, who received a Ph. D. in 1954 from the U. of Illinois, was formerly with the Ethyl Corp.

## Marketing

Eugene Moriarty has been elected assistant vice president-new projects, for Scientific Design Co. He will serve in the Sales Department. Moriarty was previously with Vitro Engineering, as manager, New Chemical Projects. James F. Whiting has been named sales representative for Hycar special purpose rubber for B. F. Goodrich Chemical. He will serve the New York City, Connecticut and Western Massachusetts areas.

John R. Britt has been named eastern manager, rocket motors, B. F. Goodrich Aviation Products Division. Britt was manager of government sales for the company Sponge Products Division.

Eugene D. Crittenden, Jr. has been appointed senior technical sales-service representative, Hercules Powder Naval Stores Department. He moves up from the post of technical development representative, Naval Stores Home Office Staff.

Herbert W. McNulty moves into the position of manager, market research, for Allied Chemical National Aniline

Division. He will be responsible for projects dealing with the market potentials and marketing methods for more than 2000 company products.

Emo D. Porro has been named vice president, marketing, Arnoux Corp. He will be responsible for marketing of all the Los Angeles firm's products, including Astra Technical Instrument Corp. and Automation Electronics.

Patrick R. Beck has been assigned to the Chicago office of Air Reduction Chemical as sales and development representative. He will cover Indiana, Michigan and Ohio territory.

At Dorr-Oliver, V. P. Chwalek has been transferred to the newly formed Petroleum & Petrochemical Sales Division. His headquarters continue at the Chicago office. Assigned to the new division as sales engineer for the Western region is Roy D. Eddington.

Joseph K. Roberts has been elected a director of Scientific Design Inc, where his work as consultant will be primarily to study long-range plans for expansion and diversification of the Scientific Design Group. Roberts, recently retired director and vice president, Standard Oil (Indiana), holds over 30 patents in the general refining field.

## Necrology

Harry K. Ihrig, 62, vice president, research, Allis Chalmers. Before joining Allis Chalmers in 1950, he was director of laboratories and vice president, Globe Steel Tubes Co. for sixteen years. A research professor in Biophysics at Marquette U.'s graduate school, he was cited in 1949 by the U. of Wisconsin College of Engineering for his contributions and inventions, particularly in the field of metallurgy. Ihrig held 22 patents.

A merger between Federal Chemical and National Distillers and Chemical has been approved in principle by the boards of both companies. Considered an important step in the integration of National Distillers' fertilizer chemicals operation, the merger provides that Federal will be operated under its present name as a division of National Distillers.

Expansion of the mercury cell chlorine-caustic soda plant at Brunswick, Georgia, is underway at Solvay Process Division, Allied Chemical. Capacity will be increased approximately 100 tons a day. The added output will go to meet consumer requirements in the southeast, particularly in pulp and paper operations and in textile production.

## future meetings

### 1960—MEETINGS—A.I.Ch.E.

• NEW YORK, N. Y. Oct. 20, 1960. Hotel New Yorker. All-Day Symposium. New York Section A.I.Ch.E.

Unconventional Sources of Electrical Energy  
New Developments in Chemical Engineering.  
Anatomy of a Profession

• HOUSTON, TEX. Oct. 28, 1960. Rice Hotel. 15th Annual Technical Meeting. South Texas Section A.I.Ch.E.

Saline Water

Pollution

General Sessions (3)

Ch.E. in Latin America (Panel)

Company Policies & Engineering Registration (2 Group discussions)

• WASHINGTON, D. C. Dec. 4-7, 1960. Statler Hotel. A.I.Ch.E. Annual Meeting. See page 114.

### 1960—MEETINGS—Non-A.I.Ch.E.

• PITTSBURGH, PA. Oct. 31-Nov. 2, 1960. Mellon Institute. 31st Ann. Meeting Soc. of Rheology.

• RUSTON, LA. Nov. 3-4, 1960. Louisiana Polytech. Inst. 9th Ann. Instrumentation Conf.

• QUEBEC CITY, CAN. Nov. 6-9, 1960. Ch. E. Div. Chemical Inst. of Canada. Canadian Chemical Engineering Conf.

• PITTSBURGH, PA. Nov. 9-10, 1960. Hilton Hotel. The Chemical Market Research Assoc.

• LAFAYETTE, IND. Nov. 15-16, 1960. Purdue Univ. Engineering Applications of Probability and Random Function Theory. For info: J. L. Bordenoff or F. Kozin, Div. of Eng. Science, Purdue Univ.

• WASHINGTON, D. C. Dec. 12-14, 1960. National Conf. on Water Pollution. For info: R. S. Hutchings, Room 4310, HEW Bldg. South., Wash. 25, D. C.

### 1961—MEETINGS—A.I.Ch.E.

• NEW ORLEANS, LA. Feb. 26-Mar. 1, 1961. Hotel Roosevelt. A.I.Ch.E. National Meeting. Gen. Arr. Chmn.: O. F. Wiedeman, Cyanamid, New Orleans, La. & H. E. O'Connell, Ethyl Corp., Baton Rouge, La. Tech. Pro. Chmn.: A. L. Regnier, Cities Service R&D Co., 70 Pine St., New York 5, N. Y.

Brainstorming Technical Problems—G. C. Szego, Space Technology Labs., P. O. Box 95001, Los Angeles 45, Calif.

Kinetics of Catalytic Reactions—M. Bondart, Princeton U., Princeton, N. J.

Petrochemicals—Future of the Industry on the Gulf Coast—J. A. Sherred, Monsanto Chem. Co., St. Louis 68, Mo.

Filtration—F. M. Tiller, U. of Houston, Houston, TEXAS.

Settling—A. G. Keller, La. State U., Baton Rouge, La.

Future Processing Technology in the Petroleum Industry—A. F. Kaulakia, Process Res. Div., ESSO.

Education and Professionalism—R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 16, Ohio.

Mathematics in Chemical Engineering—R. L. McIntire, Mathematical Eng. Assoc., 3108 Sweetbriar, Fort Worth 9, Texas.

Evaluation of R&D Projects—L. A. Nicolai, 239 Parsonage Hill Rd., Short Hills, N. J.

Liquid-Liquid Extraction—R. B. Beckman, Carnegie Tech., Pittsburgh 13, Pa.

New Petrochemical Processes in the Area—B. G. Caldwell, Dow Chem. Co., Plaquemine, La.

Materials of Construction—R. V. Jelinek, Syracuse U., Syracuse, N. Y.

Thermodynamics—J. J. Martin, Cal. E. Dept., Univ. Calif., L. A. 24, Calif.

Use of Probability Mathematics in Economic Evaluation—A. G. Bates, Atlas Powder Co., New Murphy Rd., Wilmington 90, Del.

continued on page 134

# PYRAMID "INSTRUPACK"

(TUBING BUNDLES)

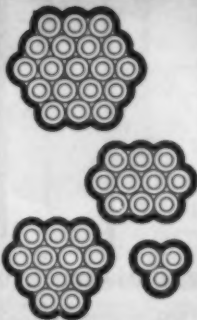


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TUBES ENCLOSED IN  
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Tubing— $\frac{1}{4}$ " O.D. x .040" Wall, .045" or .062" Sheath

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Tough vinyl outer sheath with excellent chemical atmospheric resistance. Inside tubes are Polyethylene available in standard colors with pair of telephone wire leads. Lengths to requirements.

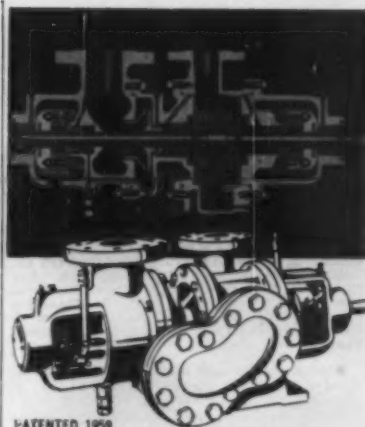
**STOCK POLYETHYLENE TUBING**— $\frac{1}{4}$ " O.D. x .040" wall and  $\frac{3}{8}$ " O.D. x .062" wall, in standard colors.

**PLASTIC COATED METAL TUBING**—standards and specials to order.

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## future meetings

from page 133

**International Chemical Industry**—L. Resen, CEP.

**New Chemical Processes**—B. G. Caldwell, Dow Chem. Co., Plaquemine, La.

**Selected papers**—E. Mannings, Shell Oil Co., Norco, La.

• **CLEVELAND, O.** May 7-10, 1961. Hotel Sheraton, Cleveland. **Joint A.I.Ch.E. National Meeting with Ch.E.Div. C.I.C.** Gen. Arr. Chmn.: H. Pforsheimer, Jr., Standard Oil Co. (Ohio), Cleveland, O. Canadian Gen. Arr. Chmn.: W. D. Gauvin, McGill Univ., Montreal, Que. Tech. Prog. Chmn.: R. P. Dinamore, Goodyear Tire & Rubber Co., Akron 16, O. Canadian Tech. Prog. Chmn.: A. I. Johnson, Toronto Univ.

**Petrochemicals as Starting Materials for Polymers**—L. P. Marek, A. D. Little, 30 Memorial Dr., Cambridge 42, Mass.

**Fluid Mechanics**—W. H. Gauvin, McGill Univ., Montreal, Que.

**Laboratory and Pilot Plant Techniques**—J.T. Cummins, School Eng., Penn College, Cleveland 15, O.

**Process Dynamics (Theoretical)**—R. M. Butler, Imperial Oil Co., Sarnia Ont.

**Synthesis Processes for Isoprene**—T. A. Burtis, Houdry Process Corp., 1928 Walnut St., Phila. 2, Pa.

**Radioactive Materials for Process Control**—J. R. Bradford, College of Eng., Texas Tech. College, Lubbock, Tex.

**Process Dynamics (Applied)**—L. M. Naphtali, Ch.E. Dept., Brooklyn Polytech., Brooklyn, N.Y.

**New Synthetic Rubber Types**—P. M. Lindstedt, Goodyear Tire & Rubber Co., Ch.E. Div., Akron 16, O.

**Coalescence**—R. Kintner, Illinois Inst. Tech., Chicago 16, Ill.

**Management Criteria for Capital Investment**—C. F. Prutton, Food Machy. & Chem. Co., 161 E. 42d St., New York N. Y.

**Chemical Engineering in Metal Refining**—

W. M. Campbell, Chem. & Met. Div., Atomic Energy of Can., Chalk River, Ont.

**Heavy Chemical Mfr.**—L. P. Scoville, Diamond Alkali, Union Commerce Bldg., Cleveland 14, O.

**Applications of High Speed Photography**—A. I. Johnson, Univ. of Toronto, Toronto 8, Ont.

**Pulp and Paper**—J. L. McCarthy, Univ. Washington, Seattle 5, Wash.

**New Research Techniques**—D. Hyman, Cyanamid, 1937 W. Main St., Stamford, Conn.

**Mixing-Fundamentals**—J. Y. Oldshue, Mixing Equipment Co., P. O. Box 1370, Rochester, N. Y.

**Mixing-Applications**—E. E. Ludwig, Rexall Chem. Co., 8909 West Olympic Blvd., Beverly Hills, Cal.

**Cash Flow Methods in Economic Analysis**—D. D. MacLaren, Esso Research & Eng., P. O. Box 215, Linden, N. J.

**Heat Transfer**—E. H. Young, Univ. Mich., Ann Arbor, Mich.

**Selected Papers**—D. J. Porter, Diamond Alkali, P. O. Box 348, Rech. Center, Palmville, O.

**Student Program**—H. B. Kendall, Case Inst., 10900 Euclid Ave., Cleveland, O.

Deadline for papers: Dec. 7, 1960.

• **LAKE PLACID, N. Y.** Sept. 24-27, 1961. Lake Placid Club. **A.I.Ch.E. National Meeting.** Gen. Arr. Chmn.: B. I. MacDonald, Jr., O. E. Co., Waterford, N. Y. Tech. Prog. Chmn.: E. R. Smoley, 30 School Lane, Scarsdale, N. Y.

**Control of Corporate Capital Investment Costs**—W. K. Menke, Pittsburgh Chem. Co., Grant Bldg., Pittsburgh 19, Pa.

**Management of Wastes at Nuclear Power Stations**—W. F. Swanton, Pfaunder Co., Rochester, N. Y.

**World-Wide Sales Challenges in the 60's in the CPI**—J. T. Costigan, Sharples Corp., 501 Fifth Ave., N. Y. 17, N. Y.

**Mechanisms of Chemical Reactions**—J. T. Horecky, Humble Oil, P. O. Box 3950, Baytown, Tex.

**Foamed Organic Materials**—M. L. Nadler, Du Pont, P. O. Box 232, Penns Grove, N. J.

**Chem. Engrs. in the Photographic Industry**

—A. K. Ackoff, Eastman Kodak, Kodak Park Works, Rochester 4, N. Y.

**Techniques to Improve Profitability of Petrochemical Processes**—G. E. Hares, Phillips Petro. Co., Bartlesville, Okla.

**Economics Theories Applied to Growth Industries**—No Chmn.

**Petrochemicals in the 60's**—No Chmn.

**Market Development in the CPI**—L. B. Hitchcock, 60 E. 42 St., N. Y. 17, N. Y.

**Bulk Fibrous Materials**—R. M. Christiansen, Stearns-Roger Mfg. Co., Denver, Colo.

**Economics of Equipment Selection**—E. E. Ludwig, Rexall Chem. Co., 8909 West Olympic Blvd., Beverly Hills, Cal.

**Selected Papers**—No Chmn.

Deadline for papers: Apr. 24, 1961.

• **NEW YORK, N.Y.** Dec. 3-6, 1961. Hotel Commodore. **A.I.Ch.E. Annual Meeting.** Gen. Arr. Chmn.: L. J. Coulthurst, Foster Wheeler Corp., 666 Fifth Ave., N.Y. 19, N.Y. Tech. Prog. Chmn.: A.V. Caselli, Shell Chem. Corp., 50 W. 50 St., N.Y. 20, N.Y.

**Fluidization**—P. A. Zenz, Assoc. Nucleonics, Inc., 975 Stewart Ave., Garden City, N. Y.

**International Chemical Industry**—No Chmn.

**U. S. Chemical Industry**—No Chmn.

**Utilization of Technical Personnel**—No Chmn.

**High Viscosity Fluids-Design Aspects**—No Chmn.

**Physical and Transport Properties**—No Chmn.

**Polymerization Kinetics and Catalyst Systems**—No Chmn.

**Heterogeneous Catalysis and Chemisorption**—No Chmn.

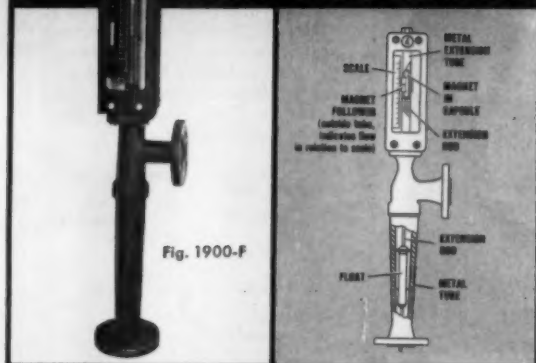
**Heat Transfer-Phase and Chemical Change Systems**—G. T. Skaperdas, M. W. Kellogg, 711 Third Ave., N. Y. 17, N. Y.

**Solid State Principles**—No Chmn.

**Flame Theory and Plasmas**—H. M. Hulbert, Am. Cyanamid, 1937 West Main St., Stamford, Conn.

**Solid State Applications**—No Chmn.

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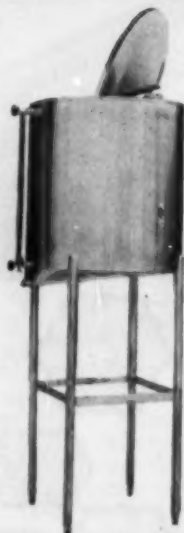
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Water Pollution—No Chmn.  
 Petroleum Processes—No Chmn.  
 Petrochemical Processes—No Chmn.  
 Hydrometallurgy—G. H. Beyer, Univ. of Mo., Columbia, Mo.  
 Volatility Processing for Spent Reactor Fuels—No Chmn.  
 Recent Advances in Ferrous Pyrometallurgy—S. V. Margolin, A. D. Little, Inc., Acorn Park, Cambridge, Mass.  
 Rationale of Pilot Plants—J. T. Cummins, Fenn College, Cleveland 3, O. & G. W. Blum, 184 Ernest Dr., Tallmadge, O.  
 Polymer Handling Equipment—No Chmn.  
 Process Dynamics, Control, and Simulation—A. E. Foss, Eng. Exp. Sta., DuPont, Wilmington 98, Del. & D. E. Lamb, Univ. of Del., Newark, Del.  
 Radiation and Furnace Design—No Chmn.  
 Selected Papers—C. M. Thatcher, Pratt Inst., 315 Ryerson St., Brooklyn, N. Y.  
 Student Program—R. O. Parker, N. Y. U. University Heights, N. Y.

Deadline for papers: July 3, 1961.

## 1962—MEETINGS—A.I.Ch.E.

• LOS ANGELES CAL. Feb. 4-7 1962. Hotel Statler. A.I.Ch.E. National Meeting. Gen. Arr. Chmn.: B. B. Eklund, Fluor Corp., P. O. Box 7030, Los Angeles 22, Cal. Tech. Prog. Chmn.: G. C. Szego, Space Technology Labs, P. O. Box 95001, Los Angeles 45, Cal.  
 The Ch.E. as a Citizen, Engineering the Defense Dollar—G. C. Szego, Address above.  
 Air Pollution—W. L. Faith, Air Pollution Foundation, 2886 Mission St., San Marino, Cal.  
 Air Pollution (Evening Panel)—A. J. Teller, Colonial Iron Works, Cleveland, Ohio.  
 Ch.E. in the Food & Biological Ind.—J. C. Harper, Univ. Cal., Davis, Cal.  
 Ch.E. Aspects of Space Flight—A. E. Humphrey, Univ. of Pa., Philadelphia 4, Pa.  
 Ch.E. Aspects in Space Nutrition—J. J. Konikoff, M.S.V.D., O.E. Co., D & Luzern Sts., Philadelphia 4, Pa.

Competitive Nuclear Power—R. B. Richards, A.P.E.D., G.E. Co. San Jose, Cal.  
 Heat Transfer in Rocket Nozzles—R. S. Levine, Rocketdyne, 6633 Canoga Ave., Canoga Park, Cal.  
 Petroleum Production—No Chmn.  
 Hydrogen Cracking—No Chmn.  
 Elastomer Technology—E. G. Partridge, 3551 University Ave., U. S. C., Los Angeles, Cal.  
 Education and Humanities—No Chmn.  
 Plastic Materials Under Extreme Conditions—K. N. Lemons (?)  
 Important Ch.E. Problems of the Future—R. S. Schecter, Univ. of Texas, Austin, Tex.  
 Drying-Fundamentals—R. E. Peck, III, Inst. Tech., Chicago 16, Ill.  
 Drying-Equipment—F. H. Stratman, Gen. Am. Transport. Co., 135 So. LaSalle St., Chicago 90, Ill.  
 Fluids—No Chmn.  
 Mathematical Optimization Techniques in Ch.E.—G. J. Hsieh, Un. Carbide Corp., 30 E. 42 St., N. Y. 17, N. Y.  
 New Techniques in the Recovery of Chemicals from Saline Deposits—D. E. Garrett, Assoc. Chemicals, Box 447, Pomona, Cal.  
 The Chemical Engineer and the Law—R. W. Schramm, So. Nitrogen Co., 485 Lexington Ave., N. Y. 17, N. Y.  
 Ion Exchange—M. M. David, Univ. of Wash., Seattle 5, Wash.  
 Cost Reduction in New Plant Construction—No Chmn.  
 New Advances in Water Desalination—F. J. Lockhart, U. S. C., 3551 University Ave., Los Angeles 7, Cal.  
 Selected Papers—No Chmn.  
 Student Program—W. H. Corcoran, Cal. Tech., Pasadena, Cal.

Deadline for papers: Sept. 4, 1961.

• BALTIMORE, MD. May 20-23, 1962. Lord Baltimore Hotel. A.I.Ch.E. National Meeting. Gen. Arr. Chmn.: B. L. Harris, Chem. Welfare Labs., Army Chem. Cent., Md. Tech. Prof.

continued on page 137



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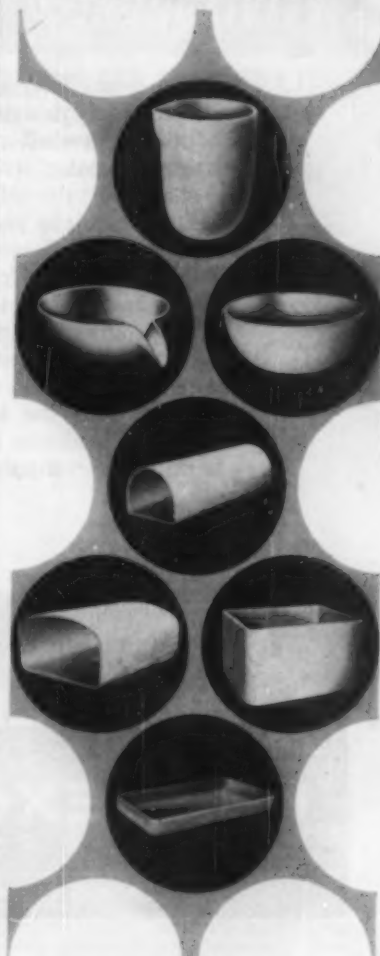
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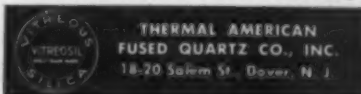


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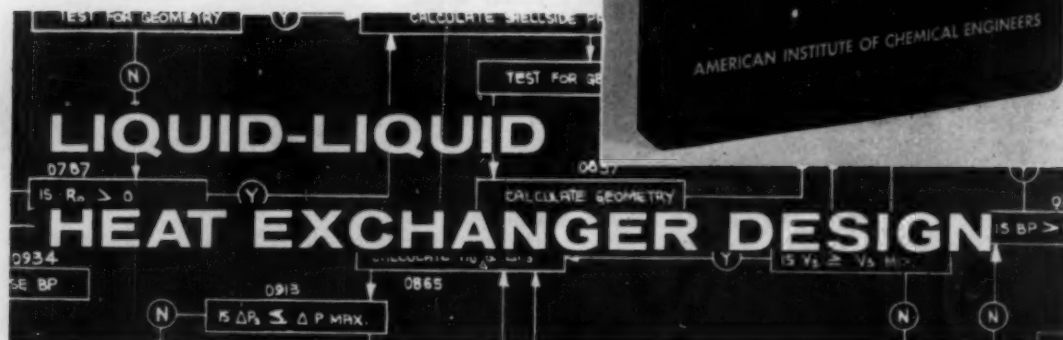
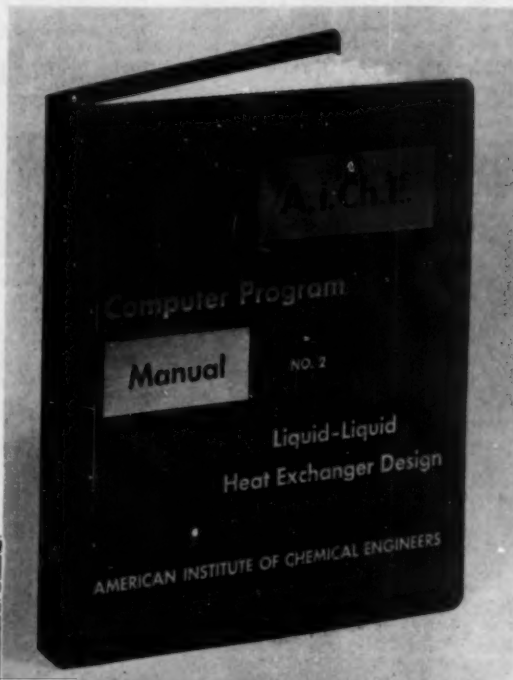
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## future meetings

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Chmn.: G. L. Bridger, Washington Ranch Center, W. R. Grace, Clarksville, Md.  
Equipment Instrumentation—No Chmn.  
Low Temperature—No Chmn.  
Fertilizers—No Chmn.  
Pesticides—No Chmn.  
Chemical and Physical Effects of Radiation—F. W. Lampe, Humble Oil, Baytown, Tex.  
Organometallic Compounds—H. A. Hulsomb, Humble Oil, Baytown, Tex.  
Unit Processes—No Chmn.  
Combustion and Aerothermo Chemistry—No Chmn.  
Behavior of Matter in Suspension in Gases—No Chmn.

• DENVER, COLO. Aug. 26-29, 1962. Hilton Hotel. A.I.Ch.E. National Meeting. Gen. Arr. Chmn.: E. E. Lauer, Univ. of Colo., Boulder, Colo. Tech. Prog. Chmn.: F. H. Poettmann, Ohio Oil Co., P. O. Box 269, Littleton, Colo.

• CHICAGO, ILL. Dec. 2-5, 1962. Conrad Hilton Hotel. A.I.Ch.E. Annual Meeting. Gen. Arr. Chmn.: G. E. Balis, Visking Co., 6733 W. 65 St., Chicago 38, Ill. Tech. Prog. Chmn.: A. L. Conn, Standard Oil Co. (Ind.) 2400 N.Y. Ave., Whiting, Ind.

## Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.  
Computers in Optimum Design of Process Equipment: Chen-Gung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.

Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.

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2. Send one copy of completed form to Technical Program Chairman for meeting selected from above list.
3. Send another copy to Norman Morash, Titanium Div., Natl. Lead Co., P. O. Box 59, So. Amboy, N. J. (Chmn. Program Comm.)
4. Send third copy to Editor, Chemical Engineering Progress, 25 West 45th St., New York 36, N. Y. Paper will automatically be considered for possible publication in A.I.Ch.E. Journal.
5. If desired to present paper in a selected symposium send fourth and fifth copies to chairman of the symposium.
6. Prepare six copies of manuscript. Send one copy to Symposium chairman or the Selected Papers chairman, whichever is appropriate.
7. Send one copy to Joel Henry, Ass't. Secretary, A.I.Ch.E., 25 West 45th St., New York 36, N. Y.
8. Send one copy to Technical Program Chairman.
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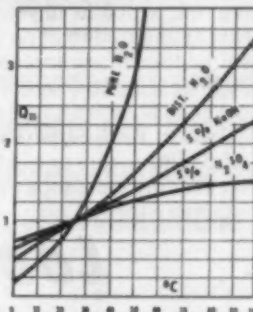
The Petrochemical and Refining Exposition to be held in conjunction with the National A.I.Ch.E. Meeting in New Orleans, Feb. 26-Mar. 1, 1961. The theme will be the Chemical Engineer's role in design and development of petroleum and petrochemical facilities.

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**CHEMICAL ENGINEER**—B.S.Ch.E. P.E. Nine years' diversified experience in refining. Process engineering, economic evaluations, and process design. Desire responsible position in Petroleum or Chemical Industry. Box 14-10.

**PROVEN CHEMICAL ENGINEER PLANT MANAGER**—of national company would like opportunity to discuss his qualifications for a top executive position with your growing chemical specialties company. Box 15-10.

**TECHNICAL OR OPERATIONS MANAGER**—B.Ch.E. 1943. Seventeen years in sales, production, development, and general manager specialty chemical field. Of value similar position or market development. Box 16-10.

**SENIOR ENGINEER**—B.Ch.E. M.S.M.E.—Age 35—for management or staff assignment—missile, space or chemical industry. Broad background project engineering, administration, government operations—propellants, rocketry and high energy systems. Box 17-10.

**NUCLEAR OR ROCKETS**—Ten years experience, five years' heat exchanger company, five years' national atomic energy lab., about fifty evening school credits, beyond M.S. in Ch. E. "A" minus average, background heat transfer, fluid flow, thermo. Minimum salary \$10,800. Box 18-10.

**CHEMICAL ENGINEER**—B.Ch.E. Age 33. Nine years' varied experience in process design, economic evaluation, R & D in oil and chemical industries. Extensive catalytic process background. Desire responsible senior process position in western Pa. area with progressive organization. Box 19-10.

**CHEMICAL ENGINEER**—B.S. and M.S. in Ch.E. Fifteen years' experience in development, process design, and process economics. Desire connection with alert, aggressive company in Midwest or West. Box 20-10.

**CHEMICAL ENGINEER**—B.S.Ch.E. family, age 28. Five years' management and supervision experience. Desire semitechnical position with a future in progressive organization. Will train and relocate. Box 21-10.

**CHEMICAL ENGINEER**—Technical sales position desired. B.Ch.E. and B.B.A. Three years' petroleum refining process and economics, plus four years' non-technical sales. Southwest preferred. Age 38. Box 22-10.

**CHEMICAL ENGINEER**—B.S., M.S. Age 39. Fourteen years' diversified experience in plastics and chemical production management. U.S. and overseas. Oriented to large and small scale operations. Desire challenging opportunity on West Coast or in foreign residence. Box 23-10.

(continued on page 140)

## SITUATIONS OPEN

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(continued from page 139)

**SUPERVISORY POSITION**—In new product development or R & D sought by Ph.D. chemical engineer with fourteen years' varied experience in R & D in the cryogenic, chemical intermediates, and petrochemicals field. Experienced in operation of plants and of pilot plants. Exceptional economics background (M.A.). Specialized in economic and technical evaluations of new ventures. Basic training in mechanical engineering. Box 24-10.

**CHEMICAL ENGINEER**—B.S.Ch.E., 1953. Seven years' diversified experience in process development and production of organic chemicals. Desire position in technical sales, service field. New England preferred location. Box 25-10.

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**CHEMICAL ENGINEER**—B.Ch.E. Do you have a need of a responsible person with a composite of sixteen years' experience in plant development, economic evaluations, and sales. If so please contact me promptly. Prefer Eastern location. Box 27-10.

**SALES EXECUTIVE**—Broad background in plastics, resins, chemical and textile fiber fields. Over fifteen years' supervisory and administrative sales experience with three major chemical concerns. Interested in challenging opportunity at managerial level. B.Ch.E., M.B.A. Box 28-10.

**CHEMICAL ENGINEER**—B.S.Ch.E., 30, married. Eight years' diversified experience with major chemical concern—R & D, project planning and liaison, process and equipment design, plant start-ups, and supervisory experience. Desire responsible position offering growth potential. Northeast. Box 29-10.

**MATERIALS ENGINEER**—B.Ch.E. (Metallurgical), age 26, family. Five years' experience in development, non-routine test, and evaluation of materials. Desire position in advanced development of engineering evaluation. Box 30-10.

**CHEMICAL/ELECTRONICS ENGINEER**—Seeks position where he can demonstrate his wide experience and seven years of academic training. Experienced at running projects and handling people and money. Prefers seaboard location. Box 32-10.

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## Positions Available New York Office

**CHEMICAL PROCESSES APPLICATIONS ENGINEERS.** 2, one senior and one junior; degree in chemical engineering, or M.S. in chemistry with considerable engineering aptitude; 1 to 10 years' experience in the chemical and process industries unit operations, process instrumentation, economic evaluation of process instrumentation. Should be strong in electronics. Familiarity with spectrophotometry, pressure, level, chromatography, colorimetry, etc. Will seek out and develop applications for process control systems in the process industries; develop and provide sales and marketing assistance to field sales engineers; train sales engineers, etc. Salaries: Br. \$8-\$10,000 a year; Jr. \$6-\$8,000 a year, also bonus program. Company pays fees. Location, Midwest. W-9565.

**CRYOGENICS ENGINEER.** graduate chemical or mechanical, with experience in the development and testing of equipment for storage, handling, and distribution of cryogenic products including storage vessels, insulating systems and techniques, mobile handling units, pumps, heat exchange devices and necessary control apparatus. Some travel. Salary, \$7800-\$8400 a year. Headquarters, New York. N. Y. W-9529.

**AREA SUPERINTENDENT.** graduate chemical engineer, with 5 to 15 years' experience, for complete operating responsibility for an HF acid plant. Must have HF acid experience. Salary, \$10-\$12,000 a year. Location, southern N. J. W-9493.

**SALES ENGINEER.** graduate chemical preferred; if chemist or mechanical engineer must have extensive experience in gas absorption and be familiar with theory; at least 20; minimum of 3 years' experience in selling equipment to the chemical and process industries, preferably dust collection, wet scrubbers, bag filters or similar equipment. Travel about 50% of time throughout the U. S. to aid and assist field representatives in closing sales of wet scrubbers. Knowledge of French helpful. Salary open. Headquarters, East. W-9489.

**REGIONAL SALES MANAGER.** chemical or mechanical graduate, with at least 10 years' direct selling including some staff management covering custom built chemical process equipment. Salary, \$12-\$14,000 a year plus bonus. Location, New York. W-9487.

**DESIGN ENGINEER.** B.S. in chemical or mechanical engineering, with at least 5 years' experience in chemical, petro-chemical or cryogenic process equipment design, to design cryogenic plant equipment such as distillation, columns, heat exchangers, gas scrubbers and piping to satisfy process cycle conditions in the production of oxygen, nitrogen, argon and hydrogen. Travel about 15%. Salary, \$9-\$11,400 a year. Location, N. Y. C. W-9481.

**PROCESS ENGINEER.** preferably with M.S. in chemical engineering or food technology, and experience in food processing covering

process evaluation, pasteurization, equipment specifications and packaging. Salary, \$10-\$11,000 a year. Location, N. Y. C. W-9458.

**ENGINEERS** with 5 to 10 years' experience on process and industrial chemical plant projects. (a) Chemical Engineer for work involving preparation of heat and material balances; preparation of process and engineering flow diagrams, performing basic engineering calculations and designs; and sizing equipment pipe lines. Ability to prepare cost estimates, operating expense estimates and comparative economic studies with supervision of construction drawings is desired. (b) Instrumentation Engineer, mechanical or chemical engineering graduate, with experience which includes the design and specifications of complete control systems for chemical and process plants. Systems are mainly pneumatic. Electronic controls experience desirable but not necessary. Salaries, \$8-\$12,000 a year depending upon qualifications and experience. Location, eastern Penna. W-9451.

**CENTRIFUGE ENGINEERS.** graduate mechanical or chemical, with 10 to 12 years' experience with process equipment for responsible positions in: (a) Technical Coordination: 3 to 5 years' technical experience with centrifuges required. Knowledge of German: reasonable freedom to travel. Will work closely with testing production, sales and customers on engineering and related matters. (b) Sales Coordination: 3 to 5 years' experience in selling centrifuges to industry; administrative ability; reasonable freedom to travel required. Will work with salesmen on major customer calls, provide training in selling and product applications, do related administrative assignments. Company may negotiate placement fees. Headquarters, upstate New York. W-9447.

**CHEMICAL SUPERVISOR.** degree in chemistry or chemical engineering with business administration courses, to cooperate with laboratory and pilot plant in the design and engineering of new chemical processes. Will assist in supervision of general plant maintenance. Should have 5 to 10 years' related experience. Location, New Jersey. W-9445.

**CHEMICAL ENGINEERS** for technical (production) control; recent graduates preferred for manufacturing production, technical control work in all phases of pulp, paper and paper product manufacturing. Also similar activities in new products such as polyurethane foam, polystyrene containers and others. Salaries, from \$6000 a year depending upon experience. Locations: Maine, Michigan and Penna. W-9436.

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**RESEARCH AND DEVELOPMENT ENGINEER.** Chemical; B.S., M.S. or Ph.D. in metallurgy, ceramics, metallurgical engineering or physical chemistry. Familiarity with and experience in metallographic methods, induction heating, vacuum melting and refining, arc melting of metals, etc. desirable. Will do research and development of metallographic and electrolytic methods for the manufacture of rare earth metals; synthesis of intermetal-

lic compounds at high temperature; high temperature properties of rare earth oxides and compounds. Salary, to \$9000 a year depending upon experience and ability. Location, Illinois. C-8286.

## San Francisco Office

**ENGINEERS.** Product, Equipment, Manufacturing, B.S. in electrical, mechanical, industrial or chemical engineering, with at least two years' experience, to supervise, conduct or assist in redesign, pilot, production on product, manufacture, assembly or test of equipment and machinery for resistors, glass sealing, enclosures, networks, electromechanical; including methods, process, improvements. Primarily non-military. For major manufacturing corporate complex. Long time growth record. Salary, \$8-\$12,000 a year. Location, New Jersey. SJ-5518.

**DESIGN, DEVELOPMENT, TEST ENGINEER.** B.S., M.S. or Ph.D. in electrical, mechanical or electrical engineering, metallurgy or physics; with one years' experience in design, development, production, testing on switches, timers, meters, power supplies, instrumentation, gas microwave, travel wave tubes, networks, transistor, resistor, potentiometer, magnetic core, pulse and data; including math, pilot prototype, production, quality, application. Primarily non-military. For major manufacturing corporate complex. Long time growth record. Salary, \$7500-\$14,500 a year. Locations, New York area, Connecticut, New Jersey, Ohio. SJ-5517.

**PHYSICISTS.** Senior, Associate, Laboratory, Assistant, with B.S., M.S. or Ph.D. in electrical, mechanical or chemical engineering, metallurgy or physics, with at least one year's experience. Will plan, supervise, conduct or assist in research-development on tubes, optics, X-rays, high-temperature, solid-state, ceramics (magnetrons, klystrons, travel wave, seals); including high math, design, construction test (vacuum and radiation instrumentation), evaluation, application, report. Primarily non-military. For major manufacturing corporate complex. Salary, \$8-\$17,000 a year. Location, New York area. SJ-5516.

**SALES, APPLICATION, COMMERCIAL ENGINEERS.** B.S. or M.S. in mechanical, electrical, physics, chemical engineering, chemistry with experience in specific areas covering one to 10 years. Need Sales-General Manager, Manager Engineer or Trainer; Applications-Manager, Engineer, Laboratory Commercial-product or technical engineer. Will direct, manage, plan, supervise, conduct or assist in marketing, advertise, economic analysis, feasibility evaluation, promotion with customers and users, OEM's, government, representative, distributors, dealers, and support programs at national, regional or local levels to develop sales of electronic systems, devices, components, cryogenic products and equipment, communication, control and signalling devices and system, power tubes, X-ray, resistors, semi-conductors or tubes, including sales headquarters, office, field, liaison, literature, catalog. Principally non-military. For major manufacturing corporate complex. Long time growth record. Salaries, \$8-\$20,000 a year. Locations, New York area, New Jersey, Pennsylvania, Massachusetts. SJ-5513.

**SANITARY EXECUTIVE.** technical graduate, possibly chemical or mechanical, to 55, well qualified by recent and extensive experience in technical management and administration; particularly interested in pollution experience related to functioning of public control boards. Must have past record of staff management and administration of technical matters; including public contact, addressing public and private individuals, groups and audiences; high level committee meetings (technical and non-technical); able to collect, evaluate, report and interpret complete body of information related to air pollution from motor vehicles. For public agency. Submit letter of application with detailed statement of qualifications, etc. availability, personnel. Salary, \$17,000 a year. Location, California. SJ-5555.

**PRODUCTION, PRODUCT, QUALITY, PLANT ENGINEERS.** B.S. in mechanical, industrial, electrical or chemical engineering, with 1 to 20 years' experience as multi-plant manager, supervisor (product, material control, quality, process, field service), engineer (factory, industrial, plant); will operate, improve, mechanize and automate manufacturing operation, fabrication, assembly, production tests on electrical, electronic, electro-mechanical components and systems, field installations and services. Primarily non-military. For major manufacturing corporate complex. Long time growth record. Salaries, \$8-\$20,000 a year and up. Locations, New York area, Rhode Island, New England. SJ-5519.



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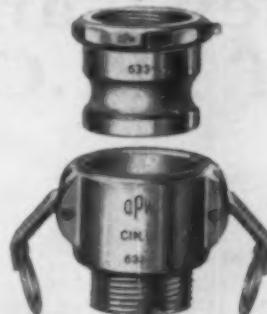
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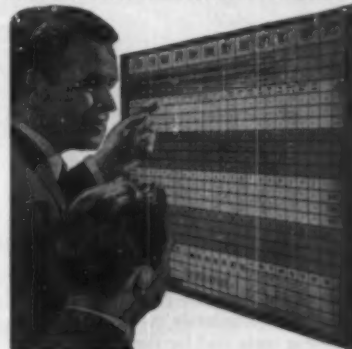
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# News and Notes of A.I.Ch.E.

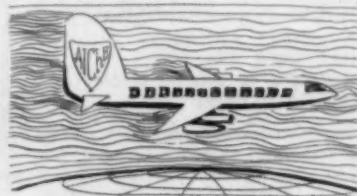
## Council at Tulsa

Council met for its usual full day of discussion at the September National Meeting in Tulsa, Oklahoma. Like most of Council's discussions in recent years, this was a session of deep thinking and long and searching inquiries into the best ways of keeping the Chemical Engineering profession moving forward. I have often thought that it would be inspiring for every member of the A.I.Ch.E. to be able to sit in on a meeting to listen to the pace of discussion, the constant flow of idea after idea to conclusions that are well thought out and in the best interests of the chemical engineering profession. Council is a heterogeneous group of men from all phases of chemical engineering. All of them are capable, and all of them bring a viewpoint and experience unique to professional societies. This proficiency and devotion, coupled with the fact that all A.I.Ch.E. members can at any time find out about all the details of Institute operation, and can see to it that their suggestions and requirements are brought to the attention of Council members, makes for a progressive profession. While I do not know the salaries of the men who sit on Council, I sometimes calculate how many hundreds of man-hours, and how many thousands of dollars in professional time, are given voluntarily to the profession by these men and by their companies. It is a tribute to the spirit of chemical engineering that Council can sit, sometimes for two days, and yet at the end of the session bring to bear on every problem the same deep interest. Many penetrating discussions are generated, but, even though there are close votes, the will of the majority, as in all democratic processes, is accepted by the minority so that the A.I.Ch.E. constantly advances. New policies are established, with everyone participating and working toward their successful fulfillment. In some of these problems it is difficult to determine where wisdom lies, but the stimulation of minds working with

minds to shape ideas is an inspiring phenomenon.

## Machine computation

Among specific accomplishments at Tulsa: we seem to be riding the jet stream of computers. The Machine Computation Committee, under Walter M. Carlson's directorship, has been working on a computer project for estimating physical properties for use in chemical engineering calculations. This has been before Council for about four different meetings, and



at Tulsa the green light was given for the A.I.Ch.E. to try to raise a sum of money for support of technical and publication activities. The actual development of a set of computer sub-routines for estimating the most useful physical properties of compounds and mixtures will be done by subcontractors, organizations skilled in this work. Emphasis will be on making the programs directly usable to chemical engineers. Since the extent of the project will depend upon funds available, the committee has developed a priority basis for determining the properties to be calculated. These include some of the following (not listed on the priority basis): atomic and molecular properties; P-V-T relations; thermo properties; phase equilibria; transport properties; reaction thermodynamics; etc. The chemical engineers are indeed fortunate to have a man of Walter Carlson's capacity and imagination to head the Machine Computation Committee, and he has put together an outstanding committee, each member capable of pioneering work in this important chemical engineering area. Ray Genereaux of duPont carried the ball in Council on

the project. Leon Cooper of Monsanto has done much of the writing of the prospectus. The Committee has two subcommittees. Publication and Technical. The vice chairman of the Machine Computation Committee is J. W. Kellett of Esso Research and Engineering.

## Professional development

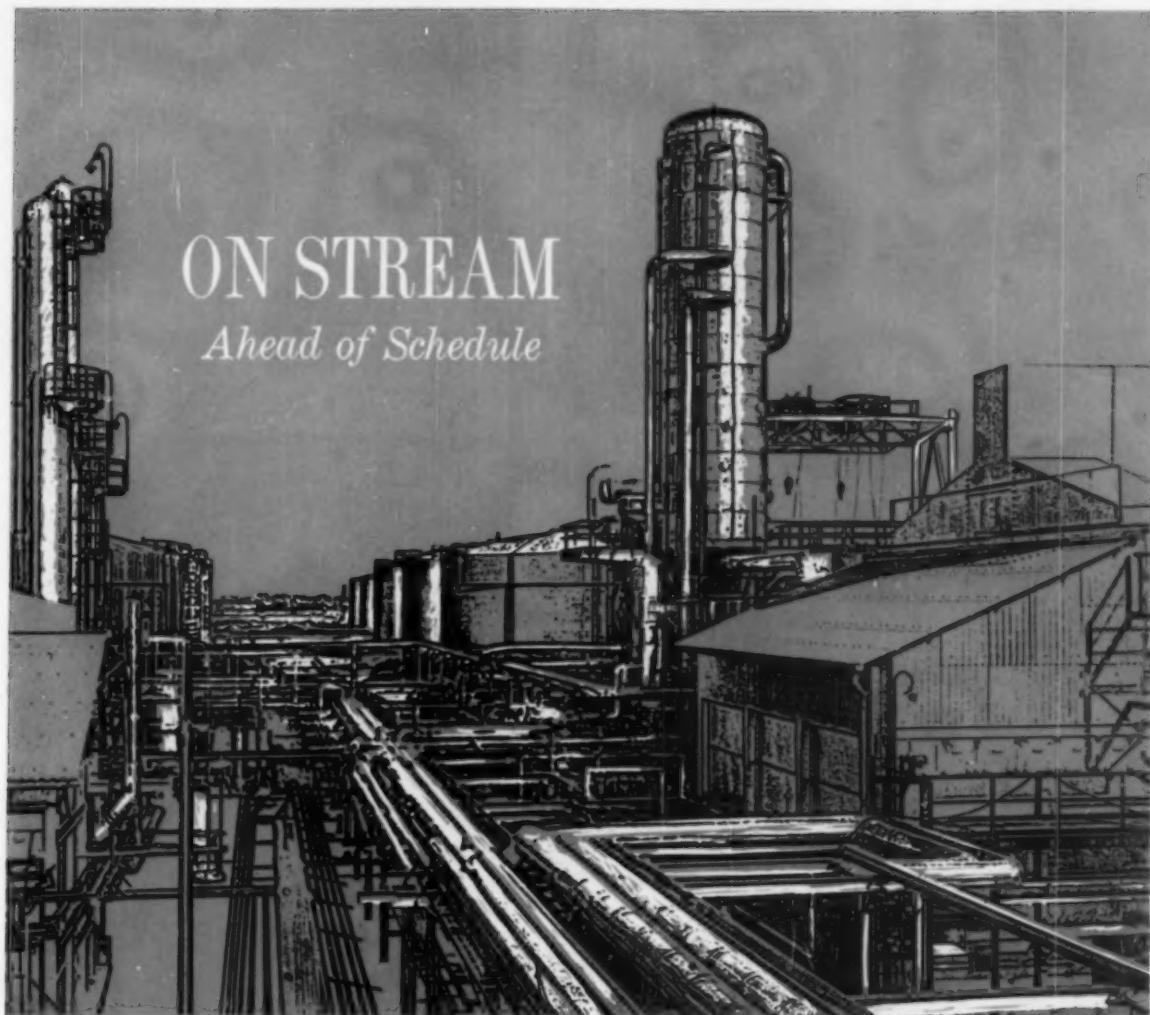
Low Coonley, chairman of the A.I.Ch.E. Professional Development Committee and professor and head of the Department of Chemical Engineering at Rensselaer Polytechnic Institute, journeyed to Tulsa to report to Council on what his committee is doing in the area of professional development. This year he has completely reorganized the group, and among the projects that they are working on is an investigation of professional attitude at the undergraduate level. They have come up with an interesting conclusion—interesting at least to me as Secretary of A.I.Ch.E.—that a strong A.I.Ch.E. Student Chapter was considered the most effective way to develop a strong professional attitude. Another activity of the Professional Development Committee is charting ways to assist Local Sections in promoting professional development at the local level, and a third subcommittee is at present studying the broad field of ethical practices and principles. A report on the development of the professional attitude at the Local Section level, along with a discussion of the whole question of professional development, will take place on Sunday afternoon at the Cleveland Meeting, May 7-10, 1961.

## Madam chairman

Without a doubt, the best looking "chairman" of any A.I.Ch.E. Local Section is owned by the Richmond group. This past month I paid a visit to Richmond to speak before the Tidewater Virginia Local Section on the changing picture of chemical engi-



neering and met my very first lady chairman, Mrs. R. E. Steward of National Aniline. Her husband is a "steward" twice-over, for he is the section Treasurer. To the best of my knowledge, Mrs. Steward, a charming and efficient chairlady, is the very first woman that we have ever had in this Local Section position. FJVA



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